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No. 29

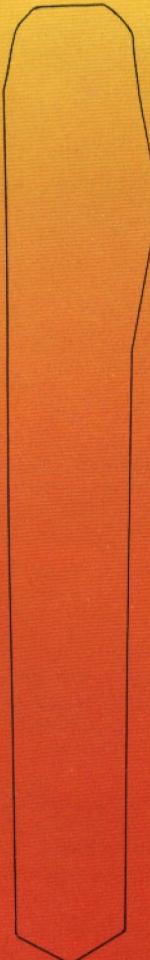
8 20 26 32 48 66 RADIO BANDS

# H ELECTRONICS

*The Maplin Magazine*

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DECEMBER 1988 TO JANUARY 1989 VOL. 8 No. 29

## EDITORIAL

Welcome to the first edition of the new style 'Electronics' with full colour pages, many new features and now it's published bi-monthly! In this first great issue we feature a fantastic Laser project priced at an amazingly low price (under £100) and a Controller for it is also available making it an ideal project for schools and colleges, or build it just for fun! Featured on the cover is a super Electronic Roulette wheel for you to build, a novel little project that all the family can enjoy, gambling the night away without the expense of a trip to Las Vegas! New regular columns include a 'news' section and 'readers letters' where you can air your views on any electronics related subjects, so if you have a gripe, some interesting info, hints or tips, constructive comments on the projects or articles published in 'Electronics', then here is your opportunity to write to us!

Finally, it is hoped that you like the new format of the magazine and that it will continue to be your favourite electronics 'tipple'. If you have any ideas for improvements we are only too willing to listen. That's it from me, see you in the next issue. Read on and enjoy!

R.T. Smith

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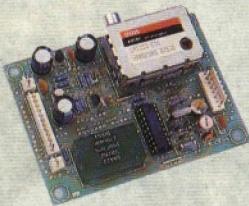
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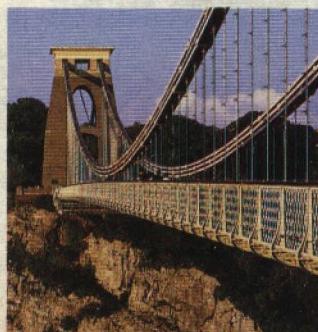
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# Air your views!

**A readers forum for your views and comments. If you want to contribute, write to the Editor, 'Electronics - The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.**

## Memories of Speakers

### Past

Dear Sir,  
The article on loudspeakers in the current Electronics stirred many tender memories for, as a radio enthusiast, I made many from the middle 20's. As a 'fretworker', I was asked about 1924 to make an enclosure for a strange diaphragm-type unit; the diaphragm of which was a metal cone about 3" diameter. Good though it was, in proper hands it could have sounded better. The balanced-armature unit was available a year later, the best being the BlueSpot (a name still with us) and Triotron and these units were assembled by amateurs in 8" chassis. British Thomson-Houston (BTH) produced one of this type with a weaker than usual restoring spring which gave a better low-frequency response. Having made the enclosure, since the H.F. response was limited, I added a wall-mounted Philips unit which had little bass, in parallel, coupled with a 0.1 $\mu$ F capacitor - my first two-unit speaker so to speak. Another idea (ex Amateur Radio) was the "Double Linen Diaphragm Speaker" which consisted of two frames, 20" and 10" square across which linen sheets were stretched. The two were joined together at the middle with a boss, and with the aid of a cross-frame, were held taught apart so that they took up conical forms in opposite directions. Several coats of cellulose varnish stiffened the linen, and the unit was suitably mounted so that the reed could be attached to the boss. I suppose it worked in a way, but it was insensitive, awkward and unsightly. I scrapped this and made my own chassis with 12" paper cone which was the envy of all my friends.

I first heard the amazing BTH Panatrophe public address system in 1927/8 in which the speaker units lay horizontal. The R.K. speaker was in two sizes, 10" and 12" and I purchased one of the latter in 1928. A feature of these units was the copper damping rings in the poles to reduce the impedance of the speech coil at HF, so I was told (it cost £6 15s which was a lot of money in those days). It performed superbly and I was using it on and off until 1972 when I gave it to the Science Museum, who were glad to receive it (the unit in Photo 5d of the article may well have originally been mine).

Mr Woodgate's information about the makers may well be right, but at the time, I was under the impression that, whereas G.E. of America carried out the research, the R.K. speakers sold here were made in this country by BTH (with whom I worked for a time) and, as I recollect, marketed by Ediswan Electric Co; the latter had a showroom at the top of Charing Cross Road not far from Oxford Street.

I do not understand the observation that permanent magnets were not suitable for use until the late 1930's for there were many makes available around 1932/3 and I still have an 8" ROLA unit purchased new in 1933 for a reasonable sum. A very unusual unit I encountered was one of USA make; the speech coil and the secondary of the matching transformer of which consisted of a single-turn of copper strip, and this performed the triple duty of centring the coil and providing the restoring force as well. Yet another early development was the Nuvolion speaker in

which the cone around the speech coil was treated to stiffen it for enhanced HF response (1935?).

I wonder whether Mr. Woodgate ever heard the daily demonstrations in the Science Museum before the war (and a little after I think) using a Western Electric unit with the 10.8m horn (flare about 3m), a treat for any discerning ears. As I said, these are memories close to my heart.

**Yours faithfully, W.F. Harms, Bexhill, E. Sussex.**

P.S. I believe that Mr. Baker (Bakers Selhurst Radio) is still alive locally.

*Mr. Harms' letter is certainly very interesting. His use of two drive units to cover bass and treble in the mid-1920's appears to be a very early case. The Double Linen-Diaphragm Speaker acted as an 'unbalanced' doublet radiator, giving, in theory, a hypercardioid directional response at low frequencies, and the massive cone assembly no doubt contributed to the low sensitivity. The 'Panatrophe' system was responsible for the insertion of that word into the language of the theatre; it became the term used for what we now have to call an analogue disc record-playing unit, and more particularly for a twin unit when these became more widely used in the 1950's.*

*With regard to the R-K loudspeakers, Mr. Harms' information is more detailed than that in the article. GE made the products in the US but I could not establish that BTH actually made them in the UK (I could not examine the screw threads on the Science Museum's unit), whereas BTH certainly advertised them, which I interpreted as 'marketing', and Ediswan would then be the 'retailer'.*

*The article does attempt to explain why permanent magnets were 'not very suitable', and thus electromagnets were preferred, for mains radios. For battery radios, there was, of course, insufficient energy available for an electromagnet, so, as indicated in the text, large, heavy, permanent magnets, giving rather less flux than desirable, had to be used. There is a contemporary reference in Chapter XIX of 'Loudspeakers' by N.W. McLachlan (1934).*

*Mr. Harms' information on the driver with a single-turn coil is particularly interesting. Such a coil is equally a 'rolled-up' ribbon, and this principle might be worth re-investigation with modern materials. The use of a stiffened central region of the cone was fairly well-known in the '30's, but the Nuvolion emphasised it as a feature. The problem was to terminate the stiffened region smoothly enough, so that serious mid-range unevenness did not occur. Finally, although I am incredibly ancient by current industry standards, I did not experience the WE 555 and horn at the Science Museum, because I was rather less than two years old on 'the day war broke out'. -J.M. Woodgate.*

## Numbers Were Too Complex For Us

Dear Sir,

I refer to the current issue of Electronics and the article on CALCS by Jeff Scott, in particular the formulae relating to the A.C. Bridge on page 46. I am certain something has gone wrong both in the printing and the

final result.

I feel it is unfortunate that the terms 'complex' and 'imaginary' are brought into these calculations because it must deter some students from gaining the advantages available. After all, when dealing with map bearings and distances precisely the same process is used, but using the terms 'northing', 'westings', 'eastings', etc., instead of the term 'j', and there is nothing complex in either. Also, I question whether  $j = \sqrt{-1}$ . Surely  $j$  merely means 'rotate 90°' or in quadrature as is stated; it is a SIGN with no value whatsoever, much as + and - are signs with no value. We all know that in algebra, with the definition given, a - term multiplied by a - term results in a positive product, yet no one ever suggests that  $- = \sqrt{1}$ , so why suggest that  $j = \sqrt{-1}$ ? If you accept the meaning of  $j$  as a 90° rotation and that two 'j' terms multiplied together produce a -ve term as a result of the 180° rotation (i.e. in opposition), then these weird terms 'complex' and 'imaginary' disappear.

As you can see, I prefer to simplify my mathematics.

**Yours faithfully, W.F. Harms, Bexhill, E. Sussex.**

*The problems with Jeff Scott's article were unfortunately not restricted to the AC bridge. All the errors are corrected as follows:*

*The example at the top of column 3 on page 43 should have read:*

$$\begin{aligned} \text{For example: } & (3+j5)(4-j2) \\ & = 12 - j6 + j20 - j^2 10 \\ & = 12 + j14 + 10 (\text{since } j^2 = -1) \\ & = 22 + j14 \end{aligned}$$

## Chocks Away!

Dear Sir,

Avionics is an interesting electronics related topic; but surely it has no place in an amateur context? Wrong! (Will writers please refrain from answering their own letters, otherwise there'll be nothing left for me to do! - Ed.)

The current edition of Electronics invites airing of views and so I hope that you'll publish this letter. I have established my own avionics museum as a private hobby venture. The Museum's motto is "Taking the mystery out of flying" and the visitor can expect to receive an explanation of the principles of flying an aircraft. This is supported by exhibits of all the major flight instruments, many of which work or have been rewired to simulate their functions.



Dr. Manning leaning towards avionics, or maybe it's the gyro in the instrument he's holding.

In the division exercise below this, the denominator of the third term should have been  $16 + 4$ , thus giving 20 as shown. On page 46 the square root of the modulus should have been:

$$\begin{aligned} (r[\theta])^{1/2} &= \sqrt{r} [\theta/2] \\ (25[60])^{1/2} &= 5[30] \text{ etc.} \end{aligned}$$

In the AC bridge  $Z_1$  is the resistance of  $R_1$  and reactance of  $C_1$  in parallel. The reactance of  $C_1$  is:

$$\begin{aligned} \frac{1}{2\pi f C_1} &= \frac{1}{j\omega C_1} \\ \text{and } Z_1 &= \frac{1}{j\omega C_1} \cdot R_1 \\ &= R_1 \frac{1}{j\omega C_1} \\ &= R_1 \frac{1}{j\omega C_1 R_1 + 1} \end{aligned}$$

After substituting values and multiplying by  $j\omega C_1 R_1 + 1$  the result should be  $R_1 R_x + j\omega L_x R_1 = j\omega C_1 R_1 R_2 R_3 + R_2 R_3$

The real terms solution is correct, but equating the imaginary terms produces:

$$L_x R_1 = C_1 R_1 R_2 R_3$$

$$\text{and thus } L_x = C_1 R_2 R_3$$

We had numerous letters about this article, though nobody spotted every error. We have thoroughly checked this month's article which is now hopefully error-free. However, our apologies to our readers and Jeff Scott for the muddle in Part one.

Others are sectioned to show their mechanisms.

Civil airliners are the main theme and the display includes the world's first autoland equipment as installed in the Trident, "black box" flight recorders, and much more. For the military enthusiast there are two Vulcan bomber instrument panels. Visitors are welcome (please phone on a weekday evening 01-958 5113 to make an appointment) and the Museum is two miles from junction 4 of the M1.

Conversely, has anyone any aircraft equipment, manuals or charts to offer the Museum?

Hope that other readers will want to share my interest!

**Yours faithfully, Dr. Godfrey Manning, Edgware, Middlesex.**

# 'Hello, Who's Calling?'

by J.K. Hearfield Part 3

Even though an early Postmaster General is supposed to have said that telephones would never replace messenger boys, by the end of the First World War it had become obvious that telephones were big business. In 1925 there were almost 1.5 million telephones in the UK (and the same number in New York City), and the total was growing at a rate of 10% per year.

Much of the demand came from the cities, of course. The telephone had become an indispensable business tool. And it was in the cities, with their high telephone density, that automatic working promised the greatest benefits. Medium-sized cities could be served by state-of-the-art large exchanges capable of handling multi-digit numbers. Leeds, for example, had an automatic exchange as early as 1918, designed for 5-digit numbering and planned to grow to 15,000 lines. London, on the other hand, posed a problem on quite a different scale. Even if the technology could be grown from 5-digit to 9-or 10-digit working, the rigid numbering scheme would make the changeover from manual to automatic working hugely expensive. Mistakes would inevitably be made, in terms of under-or over-provision of costly plant, and the process would take many years, during which time London's already shaky

telephone system would get even worse.

The problem occupied engineers on both sides of the Atlantic for some time. In the end, the solution chosen was simple and elegant: flexible numbering. Subscribers were to be served by 10,000-line exchanges sited wherever they were needed, and each exchange was to have its own unique identity. To reach a subscriber on any exchange, a caller would dial that exchange's identity prefix, followed by the 4-digit number belonging to the called party. But by including at each exchange, equipment designed to read the prefix code and translate it into routing digits from the calling to the called exchange, the call could be routed down any convenient path between the two. The same hardware could be used to channel traffic to the exchange service the adjacent area (which may have been in the same building) or to an exchange many miles away across the city. Only the 'software' was different. The subscriber would neither know nor care what path the call took through the system, as long as it arrived at the right destination. The first 'director' exchange was installed by the Automatic Telephone Manufacturing Company of Liverpool in Holborn London, in 1927. It was British made, and it was the first of many.

Splitting the big cities into districts in

this way had the side benefit of making the system more user-friendly. It was decided that each district should be identified by a meaningful name, not just by a 3-digit number, and so telephone dials had to carry letters as well as numbers. The scheme eventually chosen was to map the alphabet onto the digits 2 through 0 like this:

2	ABC
3	DEF
4	GHI
5	JKL
6	MN
7	PRS
8	TUV
9	WXY
0	O

To reach a HAMPstead number the user dialled HAM, which was easy to remember, and the exchange saw the digits 426, which were easy to process. The Post Office's own main exchange was, and still is HEAdquarters. Of course, with 250 London exchanges to be labelled, some had to be renamed. HAMmersmith became RIVerside, and since HOLborn came first, GOLders Green became SPEedwell.

Even in districts which did not use director exchanges, telephones were supplied with letter-coded dials. Custom-

ers (sorry, 'subscribers') dialled O for the operator, TRU for trunk (long-distance) calls, TOL for toll calls, TEL for sending telegrams, ENG for reporting faults and requesting repairs, and so on. And it was often easier to remember a friend's number as a meaningful 7-letter word than

holding a teacup. The Neophone (rapidly re-christened the Type 162) was first issued in 1929. It was liked not only because it was easier to use and technically superior to the candlestick, but also for its elegant shape which was said to have been based on that of an Edwardian silver inkstand. It was also lighter, since its case was made of Bakelite. The photograph of the Telephone 162, Photo 1, also shows a useful additional facility - a clockwork autodialler to take the strain out of making those regular calls.

Designed as a direct replacement for the Type 150 candlestick telephones, the Type 162 used an external bellset. The obvious next step was to include the bell within the case, making the instrument easier and cheaper to install, and the result was the Type 300 range. The Telephone 332 illustrated here, Photo 2, was introduced in 1936. This model included a pull-out 'cheesetray' containing a user guide and all the dialling codes available to the subscriber. The size of the card contained in the tray is an indication of the limited range of direct-dialling in the 1930's - the list contained about 40 exchanges, compared with the approximately 4000 U.K. exchange codes listed in today's dialling code book.

## The Development of the Telephone Dial

As the telephone exchange system developed it became possible for more and more subscribers to make their own telephone connections without relying on the local exchange operator, and it became increasingly common during the 1920's for telephones to be equipped with dials. Epsom, the first U.K. automatic exchange, had opened in 1912, and by 1923 there were some 18 automatic exchanges of different types in service. By 1933 there were over 1,300, though this figure still represented only 25% of the

total number of exchanges. A dial was defined as 'a calling device arranged in the form of a rotatable disc for controlling automatic selectors or switches for the purpose of establishing a connection' and the specification included an instruction that there should be no exposed screw heads to invite tampering by the subscriber or other unauthorised person, and quite right too.

The mechanical operation of the dial is in principle very simple. Figure 1 illustrates the connection between the dial plate, the main gear wheel, the governor and the central cam. Rotating the dial clockwise winds up a clock spring fixed between the main spindle and the case and spins the governor, through gears, to its 'wound up' position. Releasing the dial allows the energy stored in the spring to rotate the whole mechanism in the opposite direction at a rate controlled by the governor.

Figure 2 is a simplified sketch of a Telephone 330's dial seen from below. The central cam is shown in (a) at rest and in (b) poised to dial the number 5, showing the changed positions of the central cam, dial springs and off-normal springs. The teeth on the central cam are numbered to show their relationship to the numbers on the dial, and the arrow shows the direction in which the central cam must turn to return to rest. The central cam also closes the dial off-normal (DON) springs when the dial is not in its rest position. These contacts short-circuit the telephone's transmission path during dialling to ensure undistorted dial pulses and to prevent unwanted clicks in the receiver. The dialling path for the Telephone 332 is illustrated in Figure 3. When the dial plate is released, the central cam returns to its normal rest position at a more or less precisely controlled speed. As the cam unwinds, the slipping cam drops the dial springs into contact with the central cam and the exposed (5) teeth operate the dial springs 5 times, thus transmitting 5 pulses

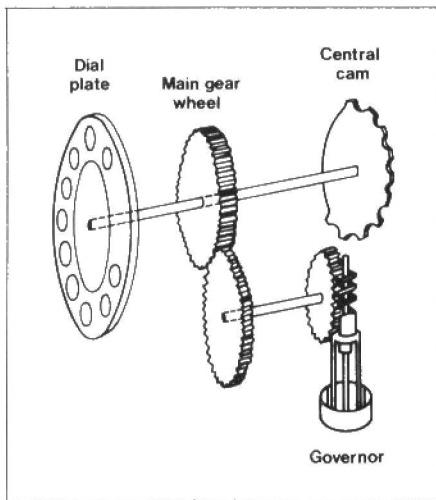


Figure 1. The main mechanical connections of a typical early telephone.

as a 7-digit number. Many decades later, when 'subscribers' had officially become 'customers', the practice of including letters on dials was abruptly dropped. Some of us miss them.

## Hand Combination Sets

The most striking change for users, though, was the introduction of a new type of telephone instrument. Known as the Hand Combination Set, or HCS, this telephone was the first type to put the microphone and receiver together in a single 'handset'. This was a revolutionary idea. A telephone call now occupied only one hand, leaving the other free for writing, or flicking through a file, or



Photo 1. The 162 telephone illustrating a useful feature - a clockwork autodialler.

Photo 2. The type 332 telephone.



down the line to the exchange. As the cam reaches its 'rest' position, the switching lever opens the dial off-normal springs again.

The design and interaction of all the parts in the dial ensure that no matter what speed the subscriber dials, a known minimum pause occurs before pulsing the first digit and between subsequent digits. This 'lost motion period', nominally 250ms long, allows the exchange equipment time to perform all the setup actions needed to process the incoming pulse-train.

The standard dialling impulse consists of a break period twice as long as the make period, with a pulse repetition rate of 10 impulses per second. So the pulses are 67ms break (line open) and 33ms make (line short-circuit). Even given a tolerance of  $\pm 10\%$ , the early governors had to be remarkably accurate to meet the required Post Office standard. It was also difficult to maintain the critical adjustment of the pulsing and off-normal springs, and the design of dials went through a number of revisions as materials and manufacturing methods improved.

## Anti-Side-Tone Induction Coil Circuits (ASTICs)

A major shortcoming of the earliest telephones had been that they made no attempt to deal with the problem of sidetone – that is, the speaker hearing himself through his own receiver. Apart from making the telephone uncomfortable to use, excessive sidetone made it less

efficient. Energy that should have been sent to line was being wasted by being broadcast through the local receiver straight into the speaker's ear. This had the unfortunate knock-on effect of making the speaker feel he was bellowing into the microphone (though he usually was, anyway) and causing him to talk more quietly, which made the transmission even worse. Transducers (microphones and receivers) were also becoming steadily more sensitive, which didn't help, and as the novelty of the Type 162 wore off it became necessary to do something about it.

The solution lay in the Anti-Sidetone Induction Coil, or ASTIC. Effectively a simple autotransformer, the ASTIC solved the problem of interfacing a 2-wire circuit (the line) to a 4-wire circuit (the transmitter

and receiver) in such a way that outgoing energy from the microphone went to line, and incoming energy from line went to the receiver.

One of the factors which influenced the choice of circuit was the Post Office's requirement that a telephone's signalling resistance should be low. This meant in practice that the transmitter resistance had to be much lower than the line impedance, and the chosen circuit enabled a low-resistance transmitter to be used effectively.

Another factor (and one which has always resulted in the ultra-cautious approach of all telecoms administrations) was that any new circuit had to work within the existing telephone network and be compatible with all existing equipment. This circuit met both requirements.

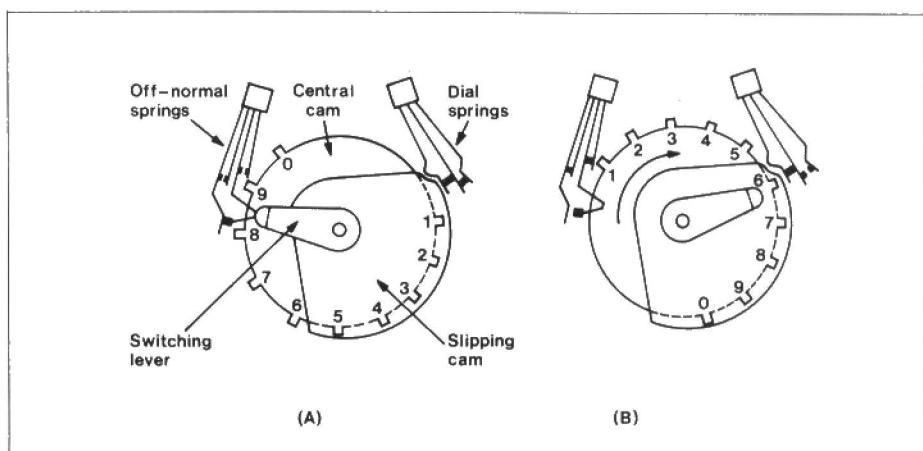


Figure 2. The 330 telephones' dial operation, (a). At rest. (b). Ready to dial digit 5.

It appeared first in the Type 232 telephone, see Photo 3, and in one guise or another it has been incorporated in virtually every other non-electronic telephone ever built.

Figure 4a shows the basic circuit. The key idea is to include within the telephone an additional impedance – the balance impedance – which is there solely to absorb unwanted energy.

Consider what happens when someone talks into the microphone, Figure 4b. Speech current flows to line through L3, so the distant end can hear what is being said. But current also flows through L2 and the balance impedance (and apparently through L1 and the receiver too, though we can ignore this for the moment). Now, if the voltage which appears across L1 due to transformer action is exactly equal and opposite to the voltage drop across the balance impedance (that is, if  $v_1 = v_2$ ), the net voltage across the receiver is zero. No current at all will flow in the receiver, so sidetone has disappeared.

The designer is free to choose the value of balance impedance and the turns ratios of the windings to give zero sidetone with any specified microphone, receiver and line.

Now suppose the distant end is talking, Figure 4c, so that speech current is flowing in from line. It flows through all three windings, but L3 is arranged to have the largest ampere-turn product so this winding effectively controls the flux in the

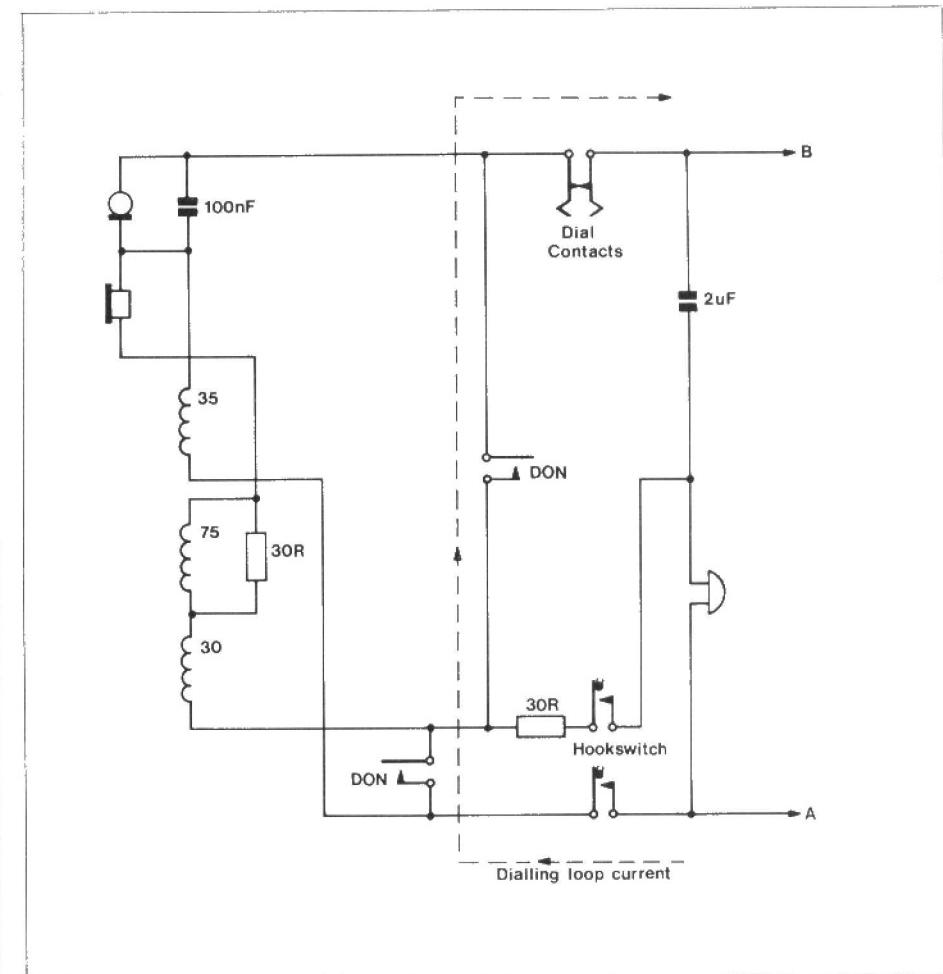


Figure 3. The dialing path for the 332 telephone.



Photo 3. The type 232 telephone.

core. The turns ratios are chosen to be such that the voltage across L1 is this time equal and opposite to the voltage across the receiver, so no current flows through the balance impedance. Nor is this all. For maximum power transfer – which means maximum efficiency – the impedance of the telephone should equal the impedance of the line. The autotransformer takes care of this too, as well as being cheap to make and reliable in operation. There is one drawback however. The circuit only works correctly if the balance impedance does actually balance the line impedance. Unfortunately, the impedance of a telephone line is anything but constant. Short lines and long lines are different, and the line impedance also depends on the impedance of the telephone at the other end. To say that the impedance of a line is 600 ohms is like saying that cars move at 30 miles per hour. Some do, sometimes. There is almost always a mismatch between the real line impedance and the value the balance impedance will balance. This is to some extend an advantage. Telephones with no sidetone sound dead and are likely to be reported as faulty, but a small amount of sidetone sounds just right.

The circuit of the Type 332 telephone shown in Figure 3 includes a 3-winding coil that looks as if it might be part of an ASTIC circuit. It is, too, and the next article will discuss how it works.

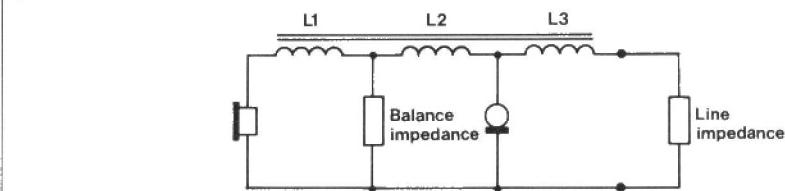


Figure 4a. The basic Anti-Sidetone Induction Coil circuit.

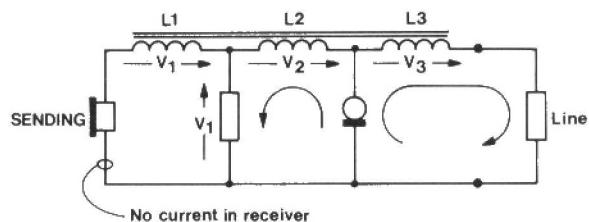


Figure 4b. The situation where  $v_1 = v_2$ , thus no current flows into the receiver and consequently no sidetone.

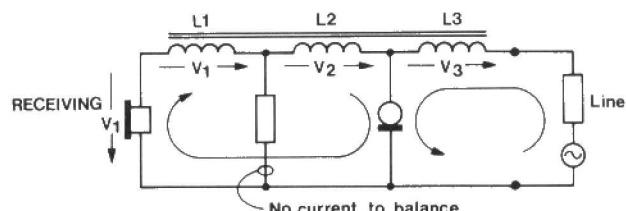


Figure 4c. Current flows through all three windings. This time, the voltage across L1 is equal and opposite to that in the receiver.

Acknowledgement. All telephone illustrations are reproduced by courtesy of the archivist at The Telecom Technology Showcase.

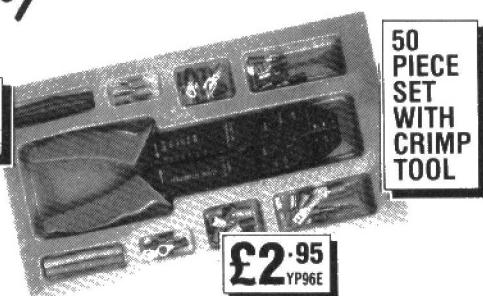
Further reading: Old Telephones by Andrew Emmerson, published by Shire Publications Ltd, Cromwell House, Church Street, Princes Risborough, Aylesbury, Bucks HP17 9AJ. Cover price £1.25.

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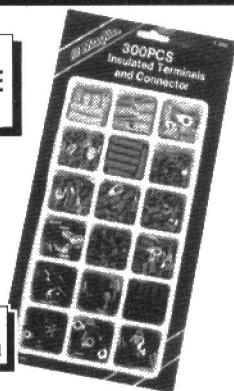


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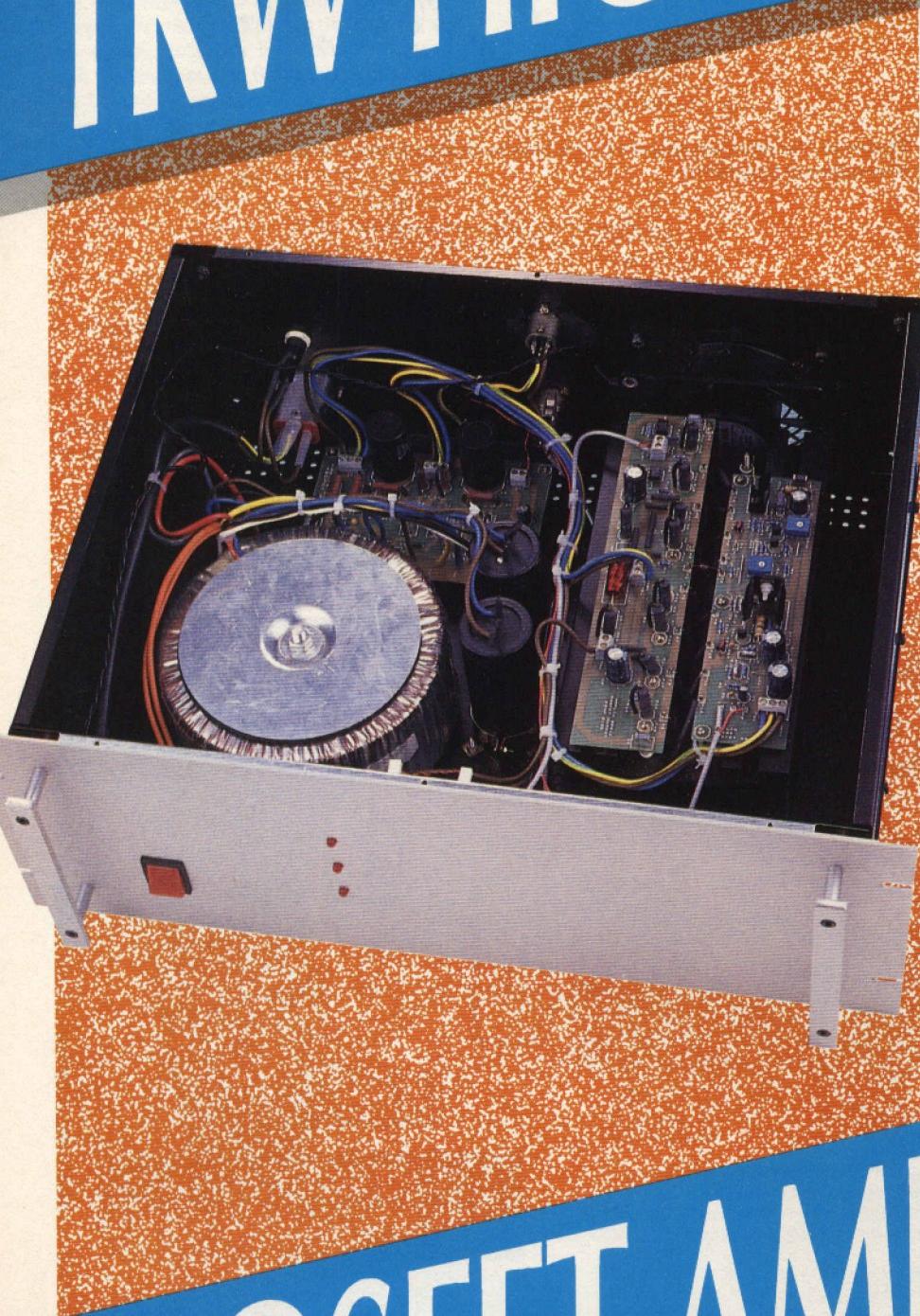
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Item	Size	Sleeve	Quantity in	Item	Size	Sleeve	Quantity in	Item	Size	Sleeve	Quantity in		
Eyellets			YP96E YP97F YT11M	Spades			YP96E YP97F YT11M	Butts			YP96E YP97F YT11M		
3.7mm	Red	4	—	25	3.7mm	Red	2	—	—	Red	4	7	20
4.3mm	Red	4	10	20	4.3mm	Red	2	10	20	Blue	4	7	15
5.3mm	Red	4	—	20	4.8mm	Blue	4	10	20	Yellow	—	—	10
3.7mm	Blue	4	—	20	5.3mm	Blue	2	10	14	Male Bullet	—	Red	—
4.3mm	Blue	—	10	20	7.0mm	Red	4	—	14	Female Bullet	—	Red	—
5.3mm	Blue	—	10	20	7.0mm	Blue	4	7	14	Crimp Tool	—	—	1
5.3mm	Yellow	—	10	Blades	7.0mm	Red	4	—	14				
6.7mm	Yellow	—	10	7.0mm	Blue	4	7	14					

**Maplin** ELECTRONICS P.O. Box 3, Rayleigh, Essex, SS6 8LR

# 1KW HIGH POWER



The Maplin High Power Mosfet Amplifier project consists of four modules: Driver and Output modules for the amplifier section, Monitor module and Power Supply module; all available separately in kit form. Articles on the construction and testing of these modules can be found in issue 26 of 'Electronics - The Maplin Magazine' (the information is also supplied with each kit!) and therefore will not be repeated again. This article concentrates on mounting a mono only version of the complete amplifier and PSU into a 19 inch 'rack mount' style case measuring 350mm deep by 176mm (4 units) high; manufactured from 1mm thick steel sheet and finished in heat cured black epoxy, with a 3mm anodised aluminium front panel.

Case kits are supplied in flat pack form with panels pre-punched and drilled, to make life easier for the constructor, and the various wires, bolts etc., can also be purchased from Maplin (see Parts List).

## Mechanical Assembly

Photograph 1 shows the actual prototype assembly with lid removed; the various component parts also can be individually identified from Figure 1. Before beginning the assembly, identify seven panels that constitute the case and temporarily place them in their correct positions. It is advisable to leave the anodised front panel wrapped up at this stage, as it can be easily scratched and marked, and it is not required at this time.

### Sub-Panel

Locate the galvanised sub-panel and orientate it with the smaller S1 cut out

# MOSFET AMPLIFIER

**Part 2**  
by Dave Goodman

positioned at the lower right hand side, as shown in Figure 2 and Photograph 2. Mount the Monitor module using four M3 x 10mm insulated spacers as in Figure 3 and Photograph 3.

#### Rear Panel

Six items are mounted on the rear panel as shown in Figure 4 and Photographs 4 and 5. Position the fan over the large panel cut-out, from the inside, with open blade side down and the air flow direction arrow, stamped on the fan chassis, facing away from the panel. Air is to be drawn IN from outside of the case and blown over the heatsink to cool the Mosfets and reduce toroidal temperatures. Ensure that the fan corner terminal block is positioned as shown, then place the wire finger guard over the panel cut out from the outside and fix the assembly with four M4 x 16mm bolts and nuts. Fit an M4 isotag terminal onto the fan chassis earthing hole, adjacent to the corner terminals, using an M4 bolt and nut.

Insert XLR connectors SK1 and PL2 into the panel from the outside. SK1 is the signal input socket with latch release mechanism, wiring shown in Figure 13, whereas PL2 is the amplifier output plug with three recessed terminal pins and non-latching! Both connectors are fixed using two countersunk M3 x 10mm bolts, nuts and washers.

Similarly, insert the Euro mains filter connector PL1 and fix with two countersunk M3 x 10mm bolts, as before, ensuring that the connector is orientated with the centre earth terminal closest to the case top (toward FS1 position).

Finally, mount the 20mm fuse holder FS1 into the panel from the outside, tighten the locking nut and insert a 6.3A fuse.

#### Base Panel

Six items are mounted onto the base panel as shown in Figure 1 and Photographs 1 and 6 through to 7. Orientate the base panel so that the various components

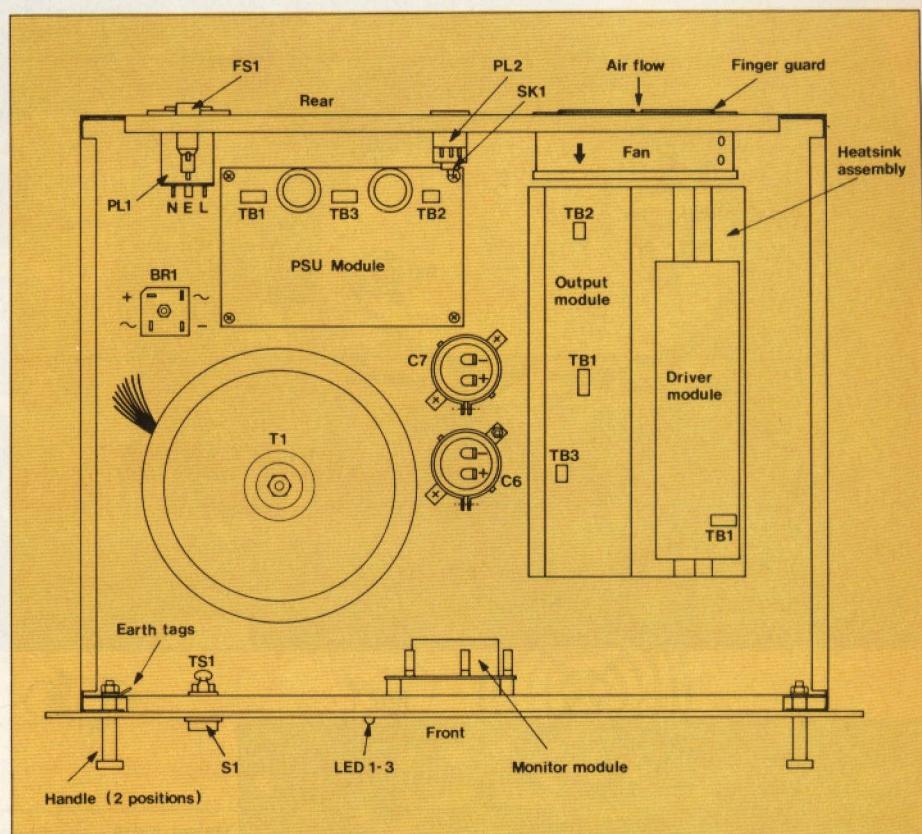


Figure 1. General layout.

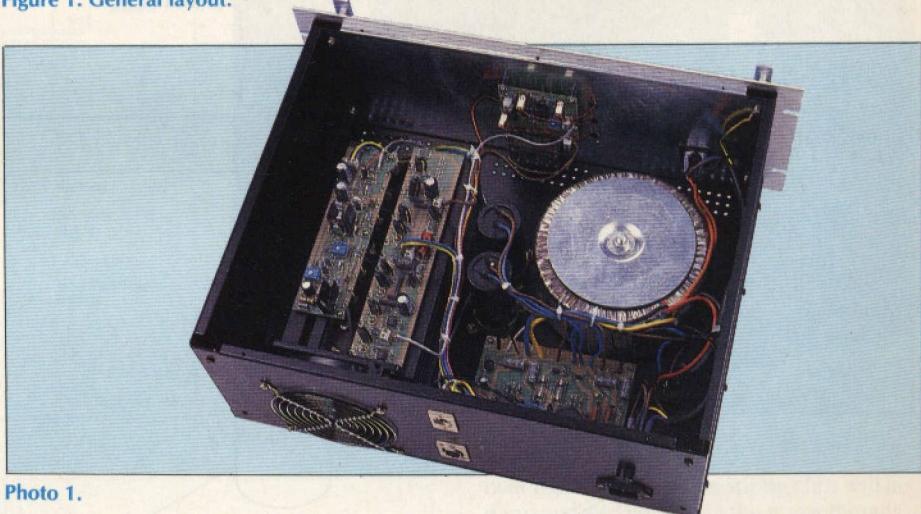


Photo 1.

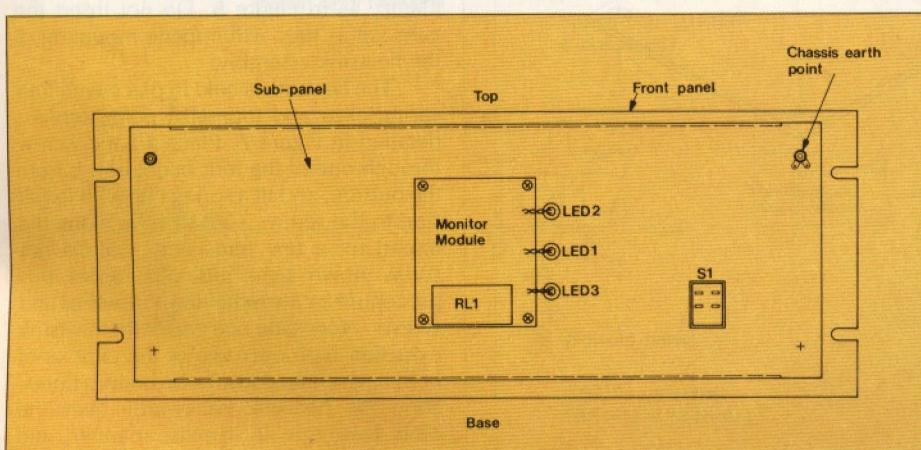


Figure 2. Sub-panel layout.

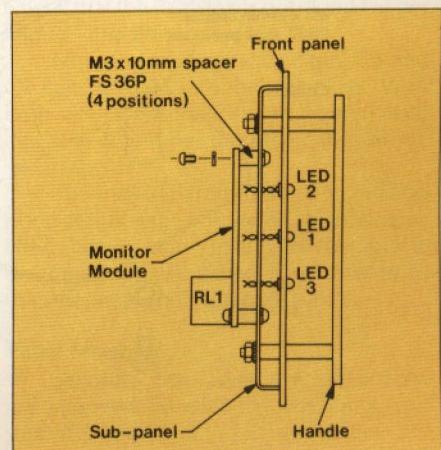


Figure 3. Side view of Front/Sub-panel.

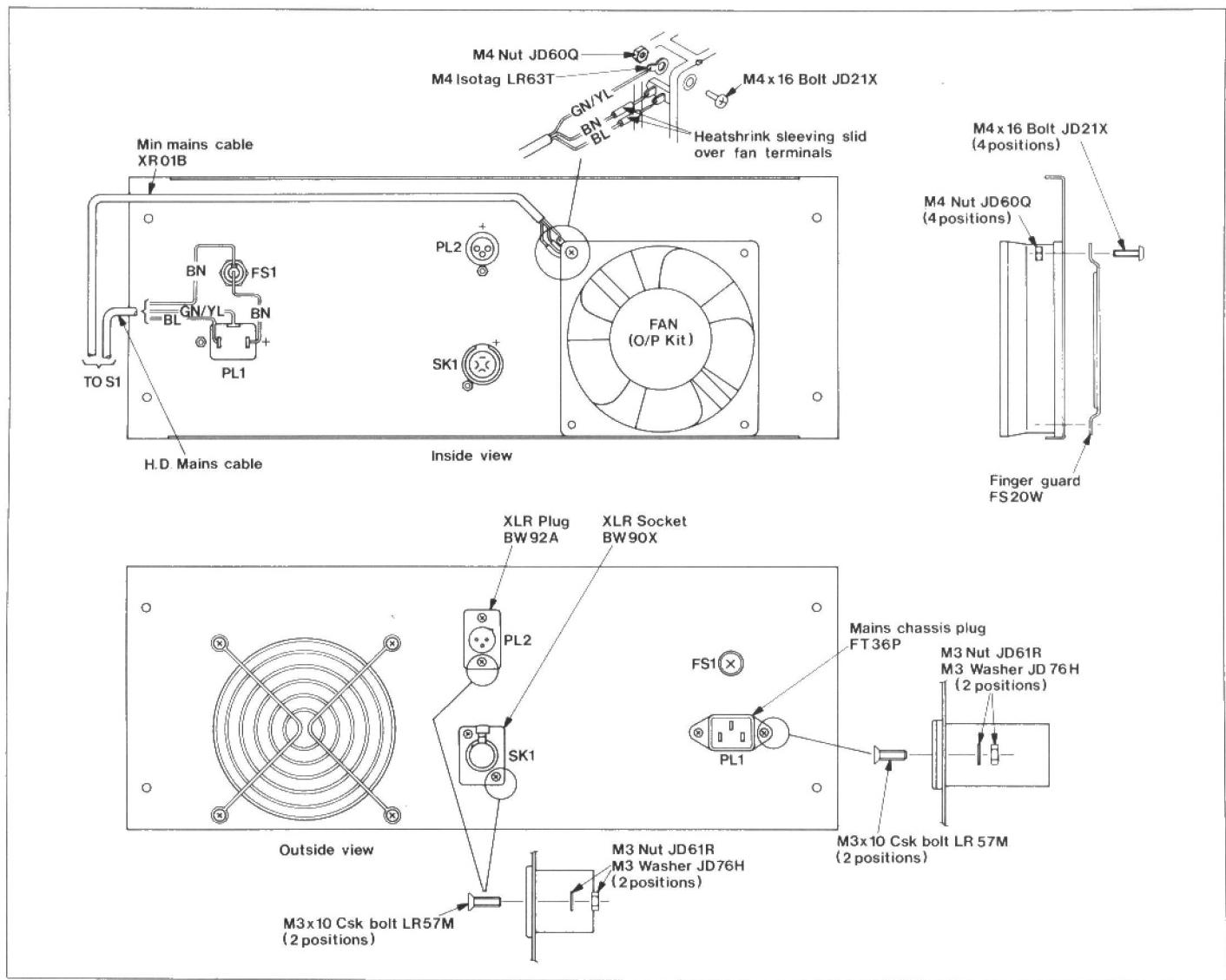


Figure 4. Rear panel layout.

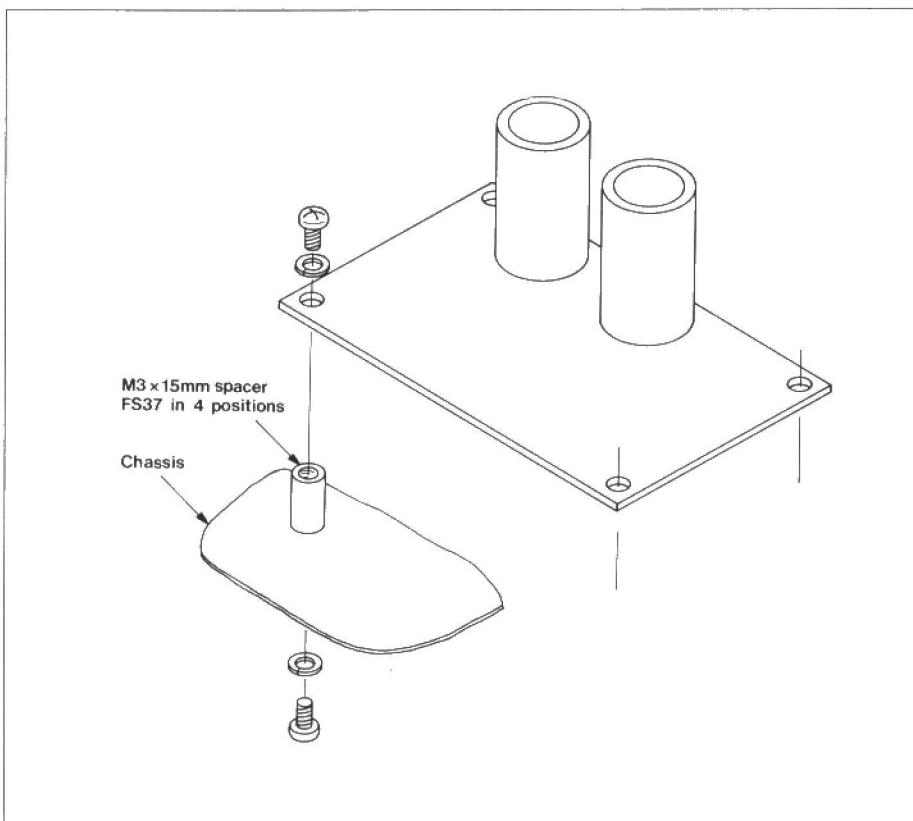


Figure 5. Mounting the PSU.

can be aligned with Figure 1 and mount the Bridge Rectifier BR1 with an M4 x 16mm bolt and nut (see Figure 8).

At the PSU module position, fit four M3 x 15mm insulated spacers in each of the four corner holes; position the module over the spacers, with 'can' capacitors C8 and C9 toward the back edge of the panel, and fit the four screws as shown in Figure 5. Power supply filter capacitors C6 and C7 are pre-fitted with mounting clamp, brackets; these should first be removed and then bolted to their respective positions using two M3 x 10mm bolts and nuts per clamp, as in Figure 6. Do not insert the cans yet as they will impede mounting of the heatsink assembly!

The heatsink is held in place with four spring clips and four 4BA panel screws, detailed in Figure 7. Place a panel screw through one of the four panel holes, from the outside, and fit a spring clip with its flat side to the screw. Turn the clip along the thread for a few turns only, but do not screw down tight just yet; repeat this procedure for the remaining three clips and screws. Now slide one end of the heatsink extrusion base over two of the clips until both have entered inside the bottom flutes. Slide the heatsink backwards over the other two clips, in likewise manner, and tighten the four panel screws just enough to grip the heatsink securely. If the screws are

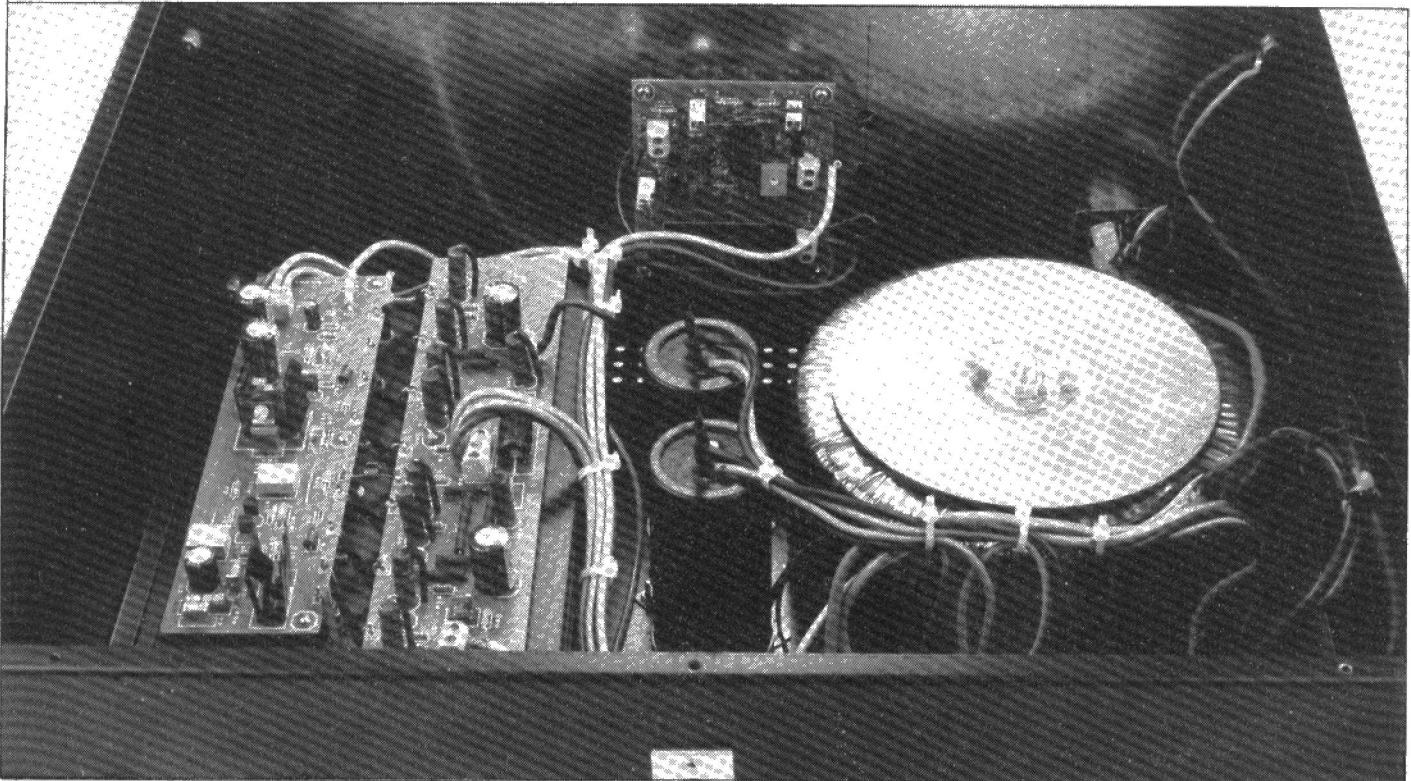


Photo 2.

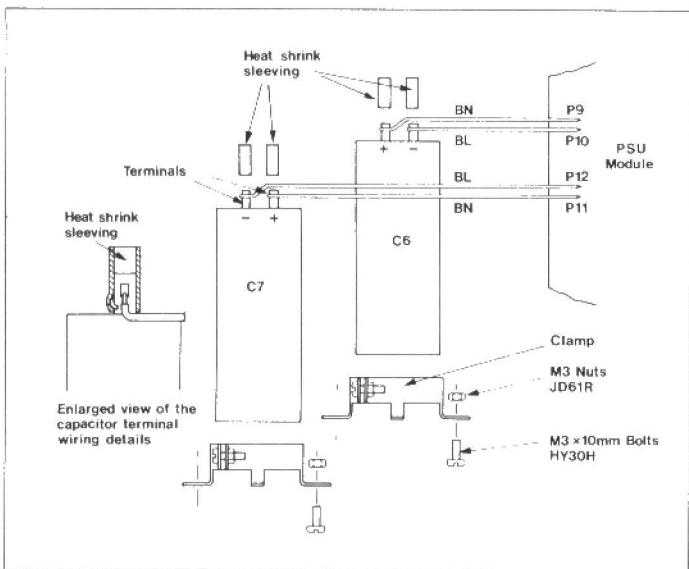


Figure 6. Mounting and wiring C6/C7.

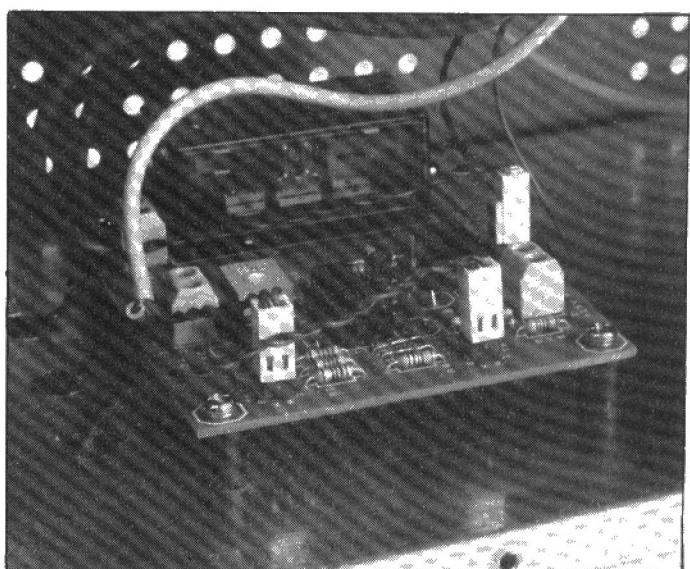


Photo 3.

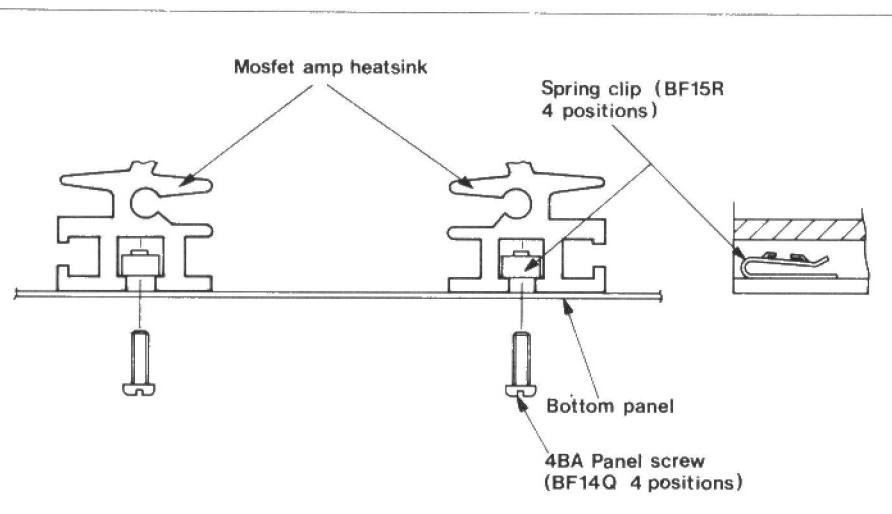


Figure 7. Fixing the Heatsink.

over tightened, then the spring clips will be damaged and fail to grip the screw threads. Check that the heatsink is positioned as per Figure 1 and Photograph 6.

Now the two can capacitors C6 and C7 can be fitted into their brackets. With both sets of terminals in line, tighten each clamp bolt and nut until the can is firmly secured.

The toroidal transformer T1 could be fitted at this stage if required, but being so very heavy and likely to bend the unsupported base panel, it is better to fit the side, rear and front panels first.

#### Panel Assembly

Separate case assembly instructions are supplied in with the flat pack and should be referred to if difficulties are experienced. Note that left and right hand panels are identical and therefore, inter-

changeable! Unwrap the anodised front panel and identify two flat aluminium handles, four tubular aluminium spacers and allen screws, four short brass spacers and nuts/lock washers. Insert two allen screws through the holes in each handle – notice the recess machined to take the screw heads – and slide an aluminium spacer over each screw thread, behind the handle! Position the front panel with mains switch cut-out S1 to the bottom left hand side. Insert both allen screw threads from one handle assembly into the two holes in the left hand side of the front panel and offer up the end plate of a side panel. Figure 1 may show this more clearly. Repeat the procedure for the right hand side handle and panel then place a short brass spacer over each allen screw thread, behind the side panel end plate! The galvanised sub-panel, now holding a monitor module, is placed over the four brass spacers and held in place with one locking washer and nut to each screw. Tighten all four allen screws/nuts, just enough to hold the four panels together; place the assembly over the base panel – inside the panel lipped edges – and fasten both sides with four self tapping screws from the case pack.

The rear panel can now be fitted and fixed with four bolts, nuts and washers from the case pack. It may be found necessary to slacken the heatsink mounting screws and move the extrusion forward slightly to accomodate the fan.

### Transformer

Figure 8 shows details for mounting T1. Insert the large bolt through the base panel from the outside and, on the inside, place a rubber insulating pad over the bolt; put the transformer onto the pad and position the eight primary/secondary wires adjacent to the bridge rectifier BR1. Fit the second rubber pad, steel disc and securing nut as shown.

**Note:** If the amplifier is to be run continuously at very high power output levels, then the toroidal will dissipate a considerable amount of heat! Under this condition the outer temperature of the steel disc reaches 50 to 55 degrees Centigrade and the inner core, even higher. Tests have shown that the toroidal runs without problem at this temperature, but it would be beneficial for long term reliability if air flow through the centre were created. Therefore, several small 'holes' (approximately 3mm) should be drilled through the base panel, steel disc and rubber pads, positioned around the centre area of T1, before assembly (not shown in photographs).

### Electrical Wiring

All heavy power and mains connections are made from heavy duty mains cable. The 2 metre length included with the PSU kit is used for DC wiring between modules, PSU capacitors, BR1 and PL2 and the 1 metre length for mains connections. Fan wiring is made from the miniature mains cable.

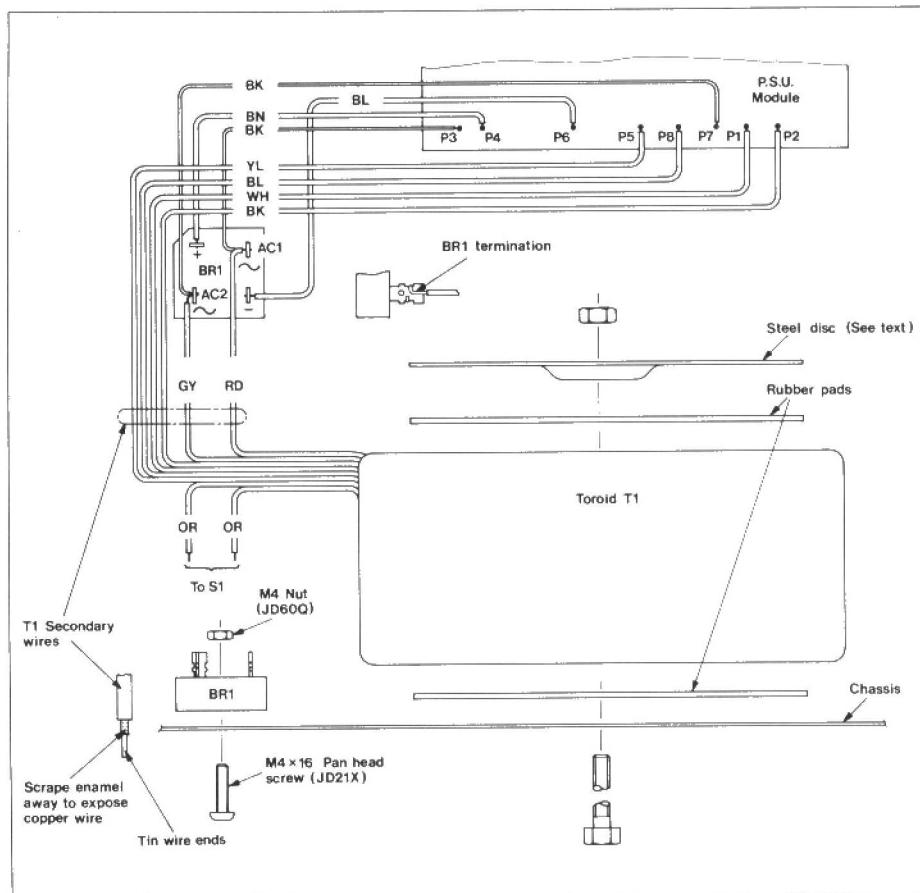


Figure 8. PSU wiring.

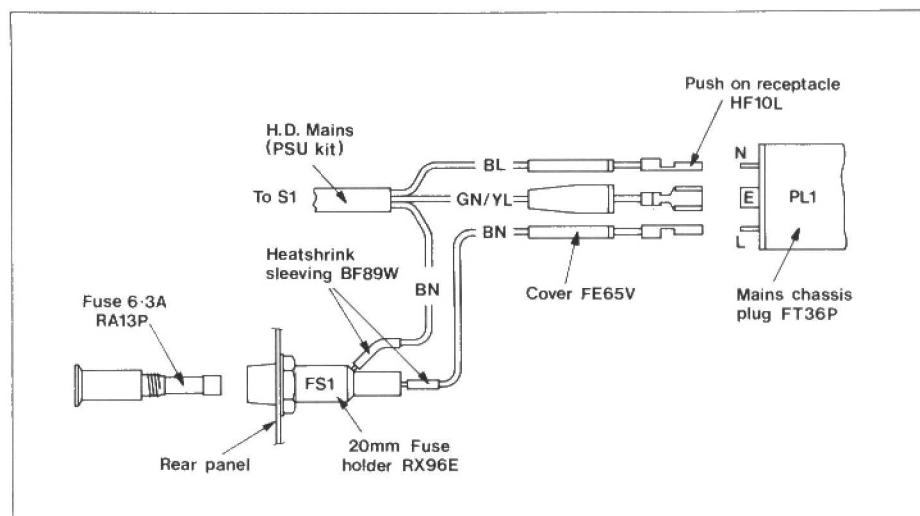


Figure 9. Wiring FS1 and PL1.

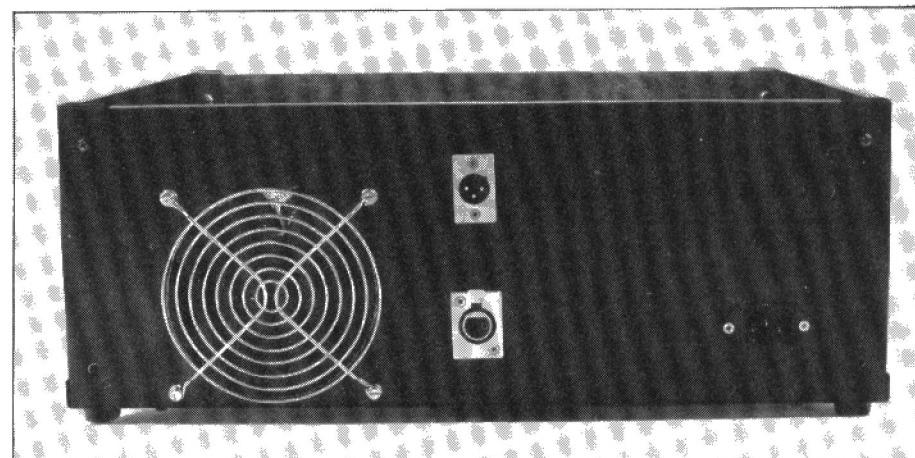
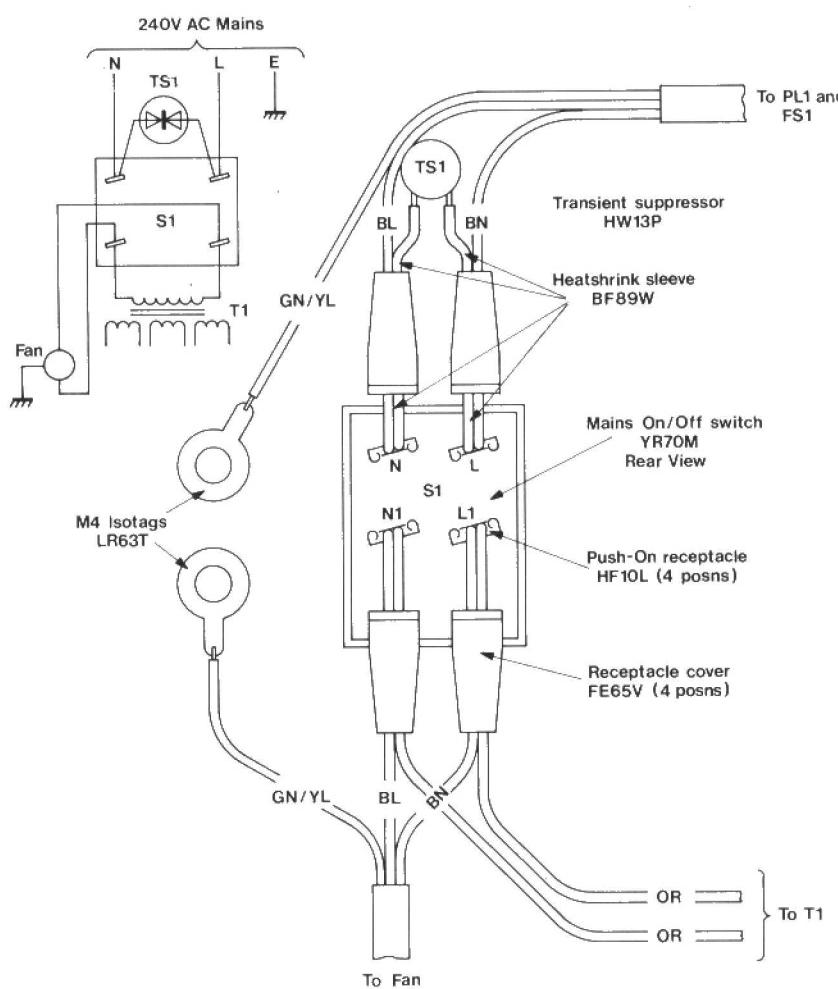
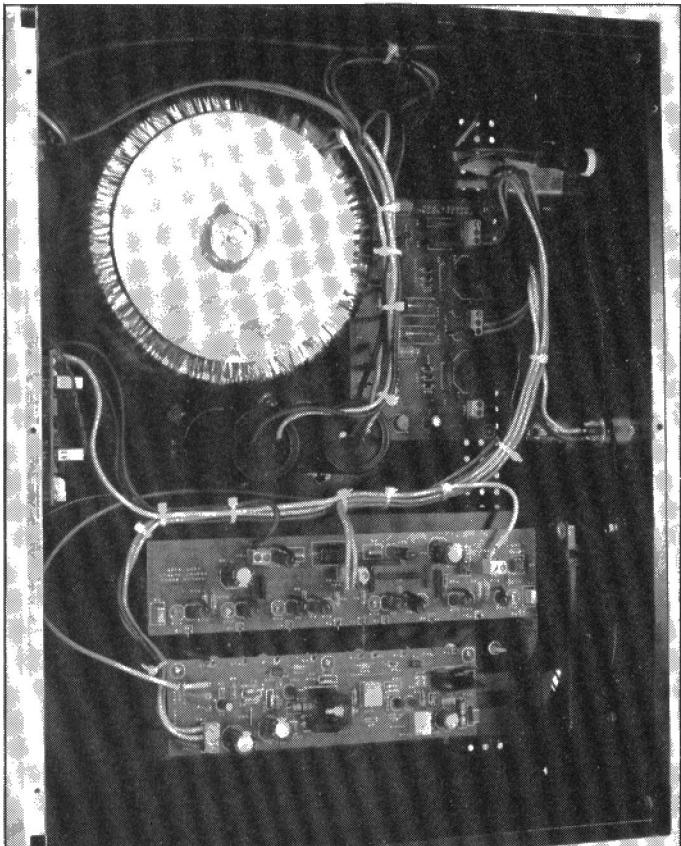


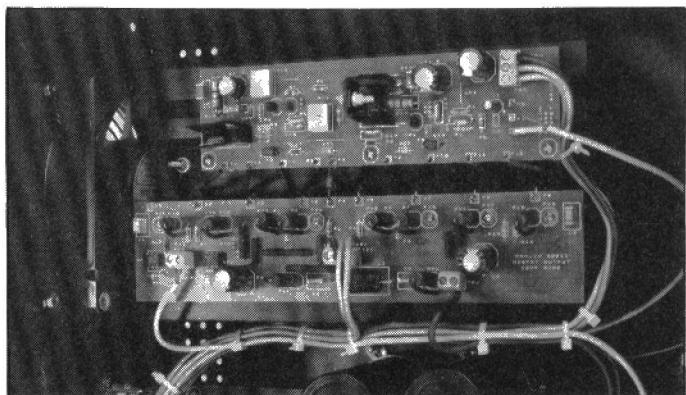
Photo 4.



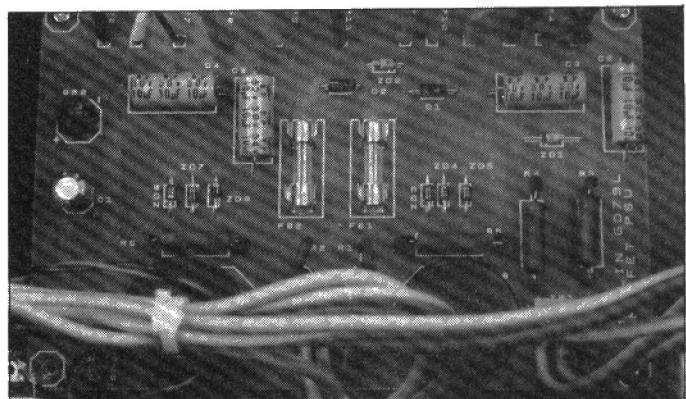
**Figure 10. Wiring S1.**



**Photo 5.**



**Photo 6.**



**Photo 7**

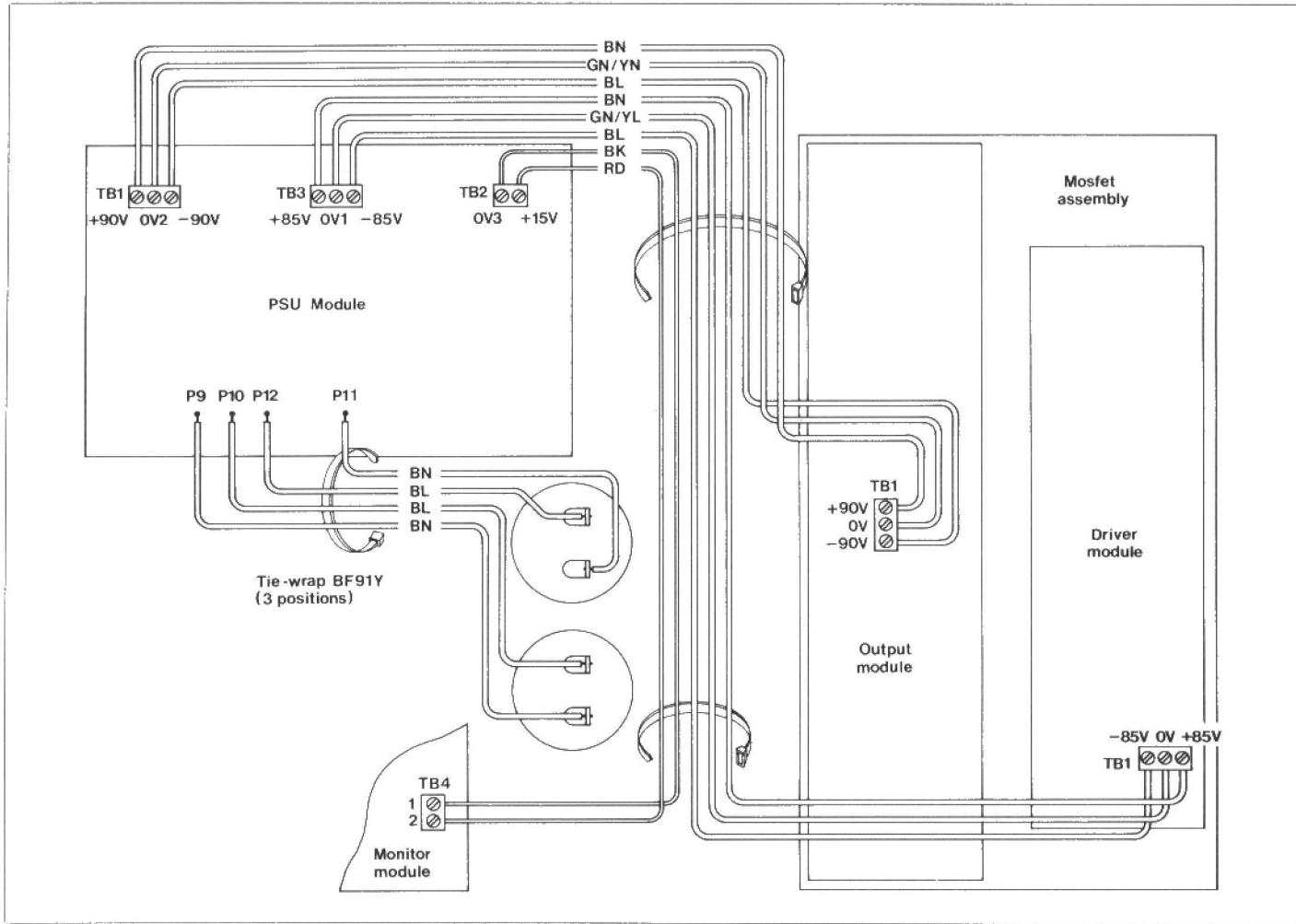


Figure 11. Wiring between modules.

Strip the outer covering from the 2 metre cable length only to expose the brown, blue and green/yellow wires. They will be used for the wire connections shown in Figures 6, 11 & 12; BR1 to PSU wiring appears in the top half of Figure 8.

#### Receptacles

Mains wiring from the input connector PL1 to switch S1 is detailed in Figures 9 and 10. Push on receptacles are used for terminating these wiring connections and insulated covers are fitted for reasons of safety. In Figure 10, the Live (BN) and Neutral (BL) wires from FS1/PL1 are terminated at S1 with a transient suppressor (TS1) connected between them. The suppressor wires are insulated with suitable lengths of heat shrink sleeving and inserted, with the mains wire, into each cover and then receptacles are fitted. Both orange primary wires from T1 and miniature mains fan wires are terminated in a similar fashion.

#### Earthing

Approximately 120mm of the green/yellow earth wire from both cables, is used for connecting to the case chassis earthing point, which is at the left hand side handle screw above S1 (see Figures 1 and 2). Solder an M4 isotag to each earth wire (Figure 10), remove the allen screw nut and washer, fit both earth tags and replace the washer and nut. An M4 isotag is also

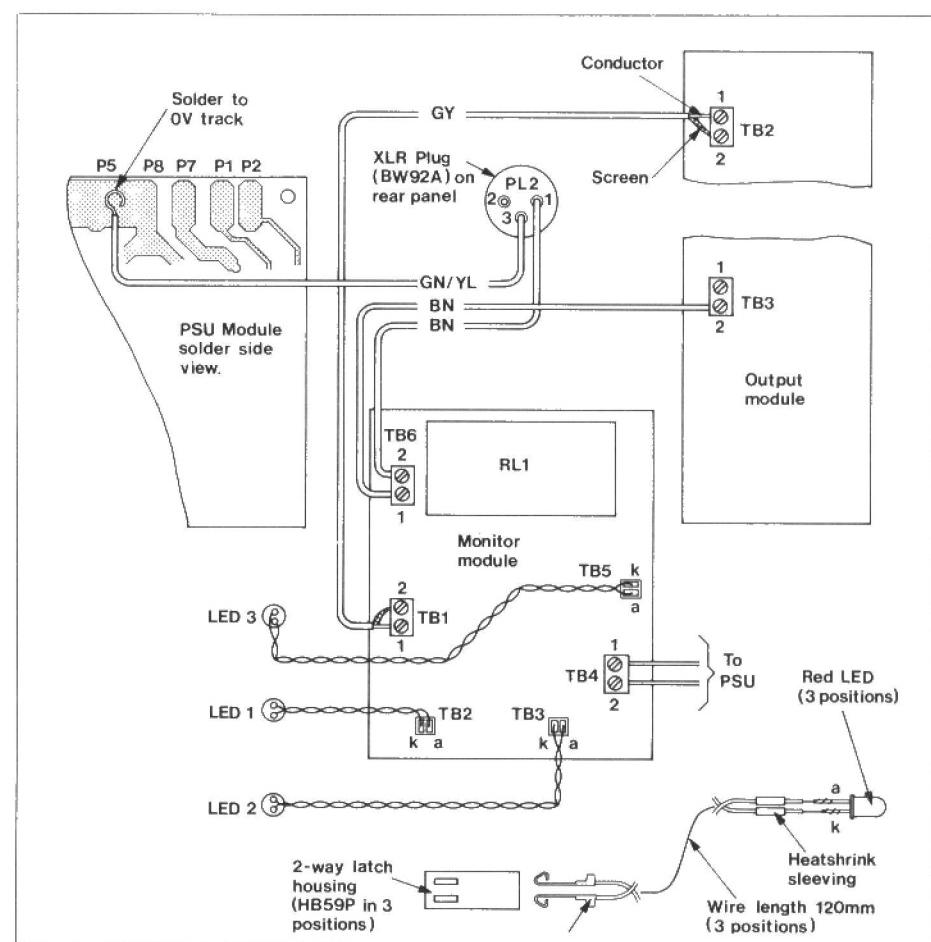


Figure 12. Wiring the LEDs.

required to be soldered onto the earth wire on the opposite end of the fan mains cable. The tag is bolted to the fan chassis as shown in Figure 4.

### Sleeving

Whenever possible, exposed wires and terminals should be insulated, especially where mains is concerned. Once wires have been prepared for soldering to a terminal, place a suitable length of heat shrink sleeving onto the wire first, solder the wire in place and slide the sleeve over both joint and terminal. Heat shrink sleeving reduces its diameter considerably with the application of heat; a soldering iron placed in close proximity will achieve this. Therefore, remember to keep the sleeve well clear of any joint until it has cooled down, else the sleeve will shrink prematurely! FS1 requires two such sleeves, as in Figure 9, and the two PSU capacitors, C6 and C7, should have sleeves placed over each terminal as shown in Figure 6. Receptacle covers are used to insulate the seven push-on receptacles on PL1 and S1 mains terminals. Place a cover over the wire first, prepare the wire end and solder onto the

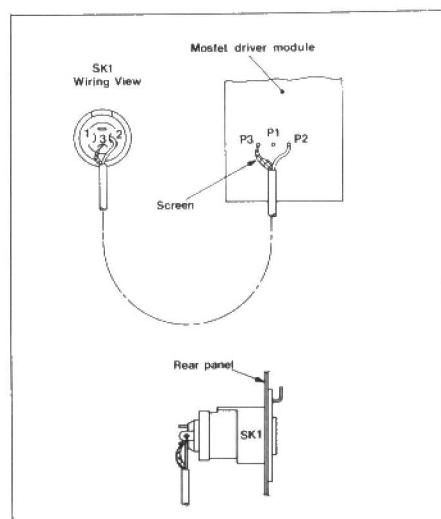


Figure 13. Wiring SK1.

push-on receptacle, fit the receptacle onto the appropriate terminal and slide the cover over both receptacle and terminal. Figure 9 and Figure 10 show the sleeving arrangements.

### Wiring Chart

Point to point wiring can be followed from the diagrams and photographs in the

article, but as mistakes are easily made, the chart given in Table 1 can be used as a guide or checklist.

### Indicator LEDs

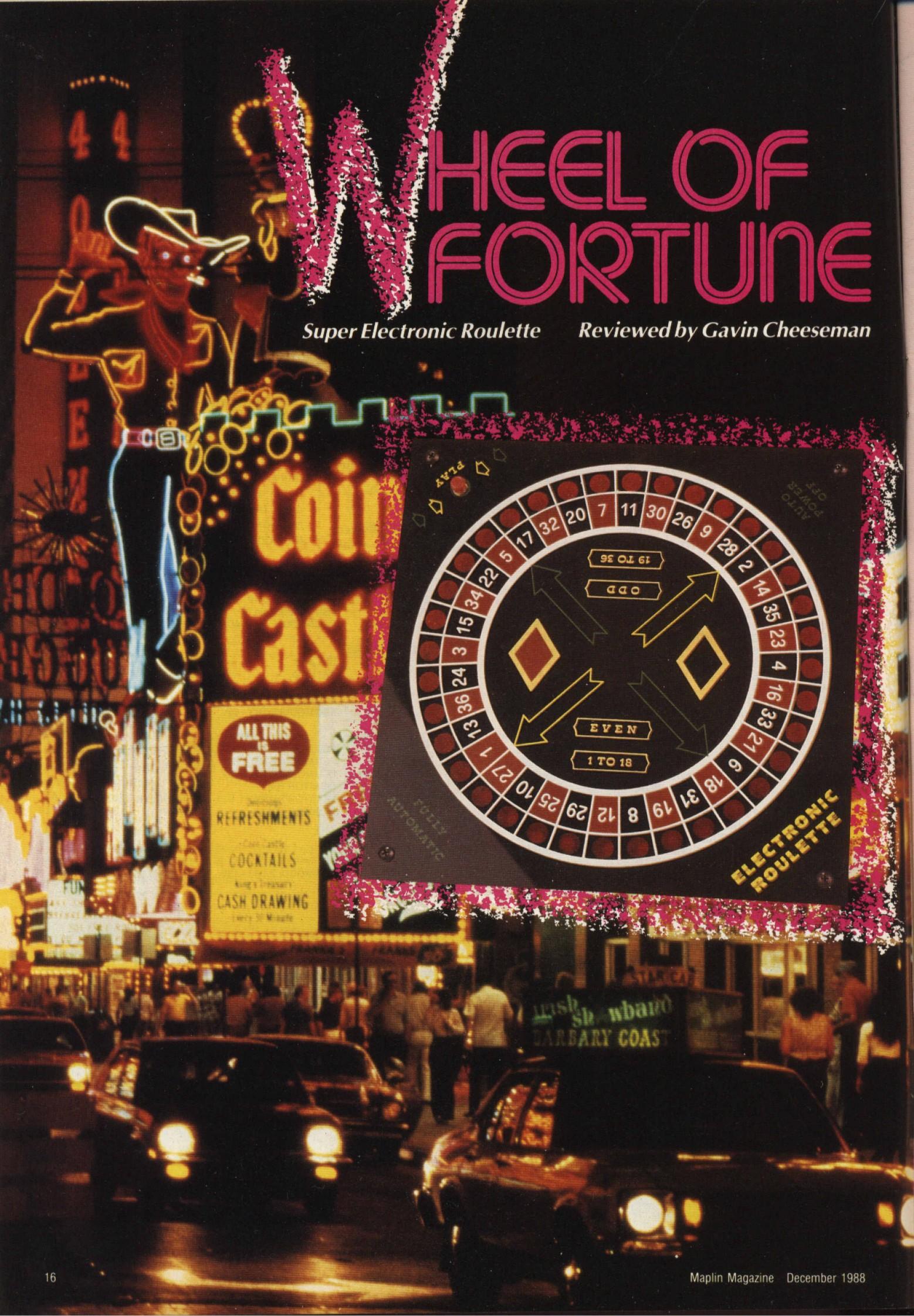
The three LEDs associated with the Monitor module are wired to 'minicon' terminals, see Figure 12, and glued into the front panel as shown in Figure 3. Cut three 120mm lengths each of the red and black hook up wire, prepare the ends and solder a red wire to each of the three LED anode leads (longest lead of the two). Solder a black wire to each of the LED cathode (K) leads and fit a suitable length of sleeving over each of the six leads and joints as shown. Carefully solder a minicon terminal onto the remaining end of each lead and insert the terminal pairs into a 2 way latch housing, noting the polarity of each wire. LED3 to TB5 wires are reversed to those of TB2 and TB3!

Apply a small amount of adhesive around the body of each LED and position them through the sub-panel into the front panel and allow to dry. Viewed from the case front, LED 2 takes the top hole position, LED 1 the middle and LED 3 to the bottom hole.

From	To	Type	Description				
1. PL1 'L'	FS1 (END)	BROWN	HD MAINS CABLE	23. C7 -	PSU MODULE pin 12	BLUE	FIGURE 6
2. PL1 'N'	S1 'N'	BLUE	HD MAINS CABLE	24. C6 +	PSU MODULE pin 9	BROWN	FIGURE 6
3. PL1 'E'	CHASSIS ETH	GRN/YEL	HD MAINS CABLE	25. C6 -	PSU MODULE pin 10	BLUE	FIGURE 6
4. FS1(CENTRE)	S1 'L'	BROWN	HD MAINS CABLE	26. PL2, pin 3	PSU MODULE 0V TRACK	GRN/YEL	FIGURE 12
5. TS1	S1 'L'	SLEEVED	FIGURE 10	27. pin 3	SK1 pin 3	SCREEN	FIGURE 13
6. TS1	S1 'N'	SLEEVED	FIGURE 10	28. pin 2	SK1 pin 2	INNER	FIGURE 13
7. FANT/BLOCK	S1 'L1'	BROWN	MIN MAINS CABLE	29. TB1 +85V	PSU MODULE TB3 +85V	BROWN	FIGURE 11
8. FANT/BLOCK	S1 'N1'	BLUE	MIN MAINS CABLE	30. TB1 0V	PSU MODULE TB30V1	GRN/YEL	FIGURE 11
9. FANCHASSIS	CHASSIS ETH	GRN/YEL	MIN MAINS CABLE	31. TB1 -85V	PSU MODULE TB3 -85V	BLUE	FIGURE 11
10. T1	S1 'L1'	ORANGE	MAINS PRIMARY	32. TB1 +90V	PSU MODULE TB1 +90V	BROWN	FIGURE 11
11. T1	S1 'N1'	ORANGE	MAINS PRIMARY	33. TB1 0V	PSU MODULE TB1 0V2	GRN/YEL	FIGURE 11
12. T1	BR1 AC1	RED	FIGURE 8	34. TB1 -90V	PSU MODULE TB1 -90V	BLUE	FIGURE 11
13. T1	BR1 AC2	GREY	FIGURE 8	35. TB32	MONITOR TB6 1	BROWN	FIGURE 11
14. T1	PSU MODULE pin 5	YELLOW	FIGURE 8	36. TB22	MONITOR TB1 2	SCREEN(+10V)	FIGURE 12
15. T1	PSU MODULE pin 8	BLUE	FIGURE 8	37. TB21	MONITOR TB1 1	INNER(I/P)	FIGURE 12
16. T1	PSU MODULE pin 1	WHITE	FIGURE 8	38. TB62	PL2, pin 1	BROWN	FIGURE 12
17. T1	PSU MODULE pin 2	BLACK	FIGURE 8	39. TB41	PSU MODULE TB2 0V3	BLACK	FIGURE 11
18. BR1 AC1	PSU MODULE pin 3	FIGURE 8	FIGURE 6	40. TB42	PSU MODULE TB2 +15V	RED	FIGURE 11
19. BR1 AC2	PSU MODULE pin 7	FIGURE 8					
20. BR1 +	PSU MODULE pin 4	BROWN					
21. BR1 -	PSU MODULE pin 6	BLUE					
22. C7 +	PSU MODULE pin 11	BROWN					

Table 1. Wiring list.

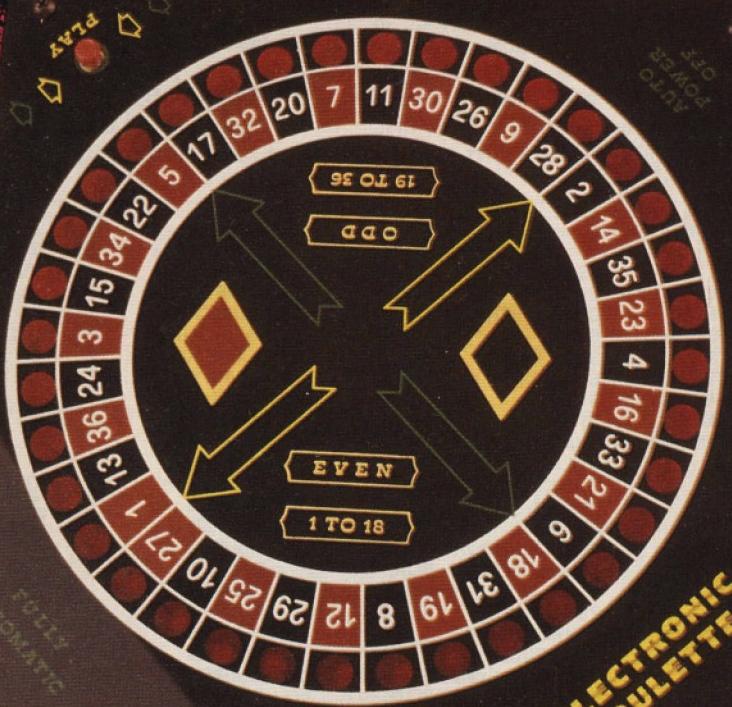
1kW H.P. MOSFET AMP HARDWARE		PARTS LIST			
MISCELLANEOUS					
PL1	Mains Chassis Plug	(FT36P)		M4 Isotag	1 Pkt (LR63T)
PL2	XLR Plug	(BW92A)		M3 Nut	1 Pkt (JD61R)
SK1	XLR Socket	(BW90X)		M4 Nut	1 Pkt (JD60Q)
FS1	A/S 6.3A	(RA13P)		4BA Panel screw	4 (BF14Q)
TS1	Transient Suppressor	(HW13P)		Spring Clip	4 (BF15R)
S1	Dual Rocker Neon Red	(YR70M)		M3 Insulated Spacer 10	1 Pkt (FS36P)
	Safefuseholder 20mm	(RX96E)		M3 Insulated Spacer 15	1 Pkt (FS37S)
	HD Mains Black	1m (XR09K)		Isobolt M4 16mm	1 Pkt (JD21X)
	Min Mains Black	1m (XR01B)		Isobolt M3 10mm	1 Pkt (HY30H)
	Cable Single Grey	1m (XR13P)		Steel Washer M3	1 Pkt (JD76H)
	7/0.2 Wire 10m Black	1 Pkt (BL00A)		Pozi Screw M3 10mm	1 Pkt (LR57M)
	7/0.2 Wire 10m Red	1 Pkt (BL07H)		Finger guard	(FS20W)
	Heat Shrink CP 48	1m (BF89W)		Latch Housing 2-way	3 (HB59P)
	Heat Shrink CP 24	1m (BF87U)		Minicon Terminal	1 Stp (YW25C)
	Tie-Wrap 98	10 (BF91Y)		Pre-drilled Case	(XM13P)
	Push-on Receptacle	1 Pkt (HF10L)			
	Receptacle Cover	1 Pkt (FE65V)			
A complete kit of parts is available, but is not shown in our 1989 catalogue.					
Order As LM65V (1kW Mosfet Amp Hardware Kit) Price £79.95					
The following item is also available separately: Pre-drilled Case Order As XM13P Price £59.95					



# HEEL OF FORTUNE

Super Electronic Roulette

Reviewed by Gavin Cheeseman



Maplin Electronics is now marketing a new range of kits from Sound Master Electronics and this is the first of several reviews that I will be producing on these products. The 'TY47 Super Electronic Roulette' kit aims to electronically simulate what is probably the most popular of games played in gambling casinos: Roulette.

My first impression of the kit was that of a relatively high quality, well thought out product; it even includes a plastic front panel, with a printed roulette wheel to give an authentic finish and I find this particularly impressive. The kit comes with a comprehensive instruction manual which takes you through the construction and test procedure step by step and this was very easy to follow. The circuit diagram and component list have been repeated here for reference.

## ***Building the Kit***

Before attempting any construction, I spread the parts out on the table in order to check that the kit was complete and also to familiarise myself with the various components. Eager to get started, I switched on my soldering iron and commenced to identify and solder the resistors in place. There are several points to watch out for when constructing the kit and, although most of these are dealt with in the instruction manual, I have included a few hints to help other constructors. Because the kit uses an SRBP (silicon resin bonded paper) type PCB, it is a good idea to keep the joint soldering time short as it is possible for the tracks to become detached from the board if overheated. After fitting the resistors it is then the turn of the links. As mentioned in the instruction manual, some of the links are very close together and for this reason it is important that they are kept as straight as possible to prevent them from shorting together. I found that the easiest way to straighten the link wire was to secure one end of the wire in a bench vice, grip the other end with a pair of pliers and pull it tight, I was then able to cut the link wire to the correct length and carefully bend the ends down ready for insertion into the PCB. If a bench vice is not available, the basic method of straightening the wire is still good as long as some other method of securing it can be arranged.

The kit includes a small buzzer which simulates the sound produced by a ball on a spinning roulette wheel and when fitting this some care must be exercised to make sure that it is not overheated. I found that the easiest way to mount the buzzer is to solder its leads on first and then to insert these through the holes in the PCB; the buzzer can then be positioned correctly and soldered in without any fear of damage to it or the tracks. I do not think that Figure 4 in the instruction manual is very clear, the buzzer is mounted on the component side of the PCB but the wires should be inserted through the appropriate holes and soldered on the track side as normal. One of the hardest parts of building the kit is probably fitting and lining up the 36 LED's

that simulate the ball on a roulette wheel. The main problem with fitting the LED's is keeping them all at the same height. I think it is a good idea to place sections of drinking straw over the leads as suggested in the instruction manual; the LED's can then be held firmly in place whilst soldering and as long as the drinking straw sections are all cut to the same length, the height of the LED's will be equal. It is also important that the LED's are kept vertical to the PCB otherwise they may not line up properly with the windows in the front panel. As no method is provided for holding the battery in position, I fitted an adhesive pad to the PCB for this purpose.

Once all the components have been soldered, I think it is always important to check your work to ensure that the components are fitted properly and to make sure that there are no problems with the soldering; this is particularly important with the LED's as I discovered that if any one LED is not connected, the game does not operate correctly!

## *Testing*

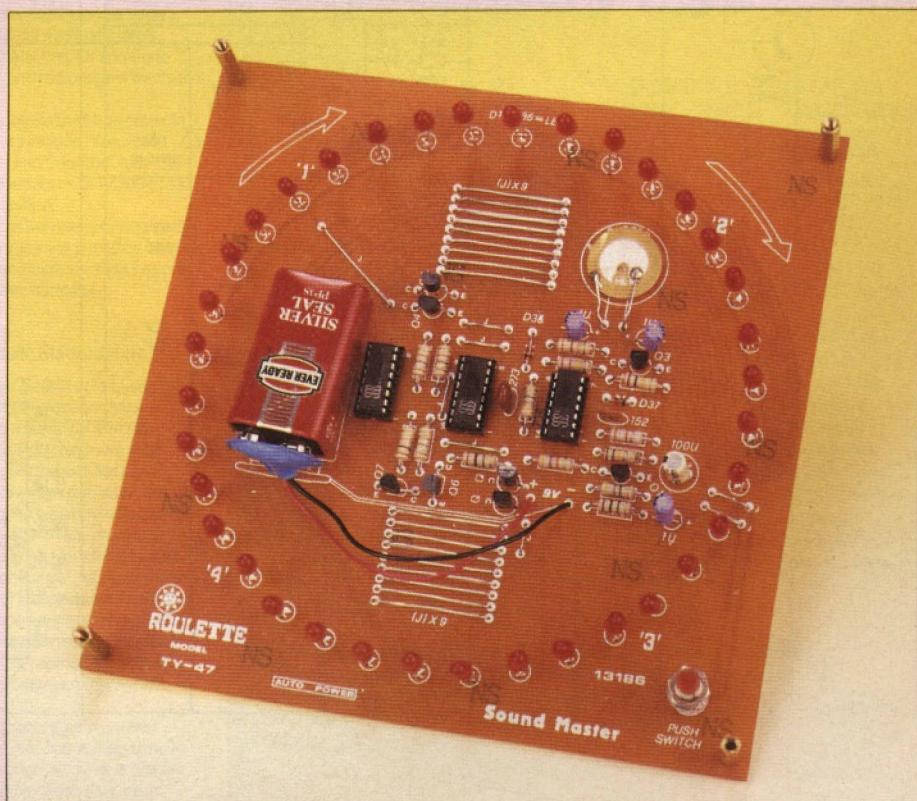
As soon as I had finished fitting the components and I was sure that everything was correct, it was then time to connect up the battery and see if all my hard work had paid off. When I pressed the play button the LED's flashed in rapid succession, giving the illusion of a ball of light moving around the board. At the same time as the LED's were flashing, the buzzer produced a bleeping sound that I thought was a good representation of the sound produced by a real roulette wheel. After a short time, the rotating effect slowed down and stopped, leaving just one LED lit. The effect is much more impressive when the front panel is

fixed in place, and this really adds a professional touch to the finished game. Because of the relatively low current drain of this project, it should be possible to run the game for many hours from a single PP3 battery. There is no need to worry about leaving the game switched on as it has a built in automatic shut off facility; if the game is not in use for a while, the LED that is left alight slowly fades until it finally goes out. The circuit draws very little current when it is in the shut off mode and I found this facility extremely useful because it eliminates any risk of an unexpected flat battery!

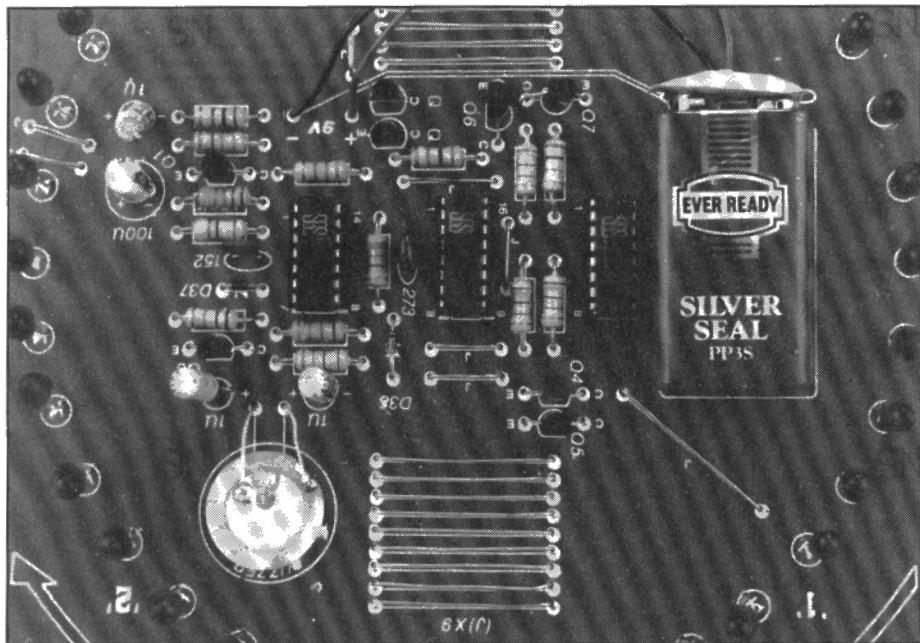
One thing that is not included in the kit is a housing into which the finished roulette wheel can be fitted. Although it is not strictly necessary and has no effect on the operation of the game, I recommend that some kind of base is fitted to protect the underside of the PCB. A simple but effective box may be made from a few offcuts of wood, this will help to protect the PCB from wear and tear and can, at the same time, add to the authenticity of the finished game.

## *Playing the Game*

In addition to the roulette wheel, a roulette table and some 'chips' are required to play the game. The 'chips' are counters which are placed over the chosen number (or set of numbers) on the roulette table to indicate the amount of money that has been bet and these are marked to indicate the value that they represent. There is a roulette table layout provided in the instruction manual. The chips however have to be improvised, and these can be made from thin card or some similar material. It is interesting to note that the



**The circle of LED's that make up the roulette 'wheel'.**



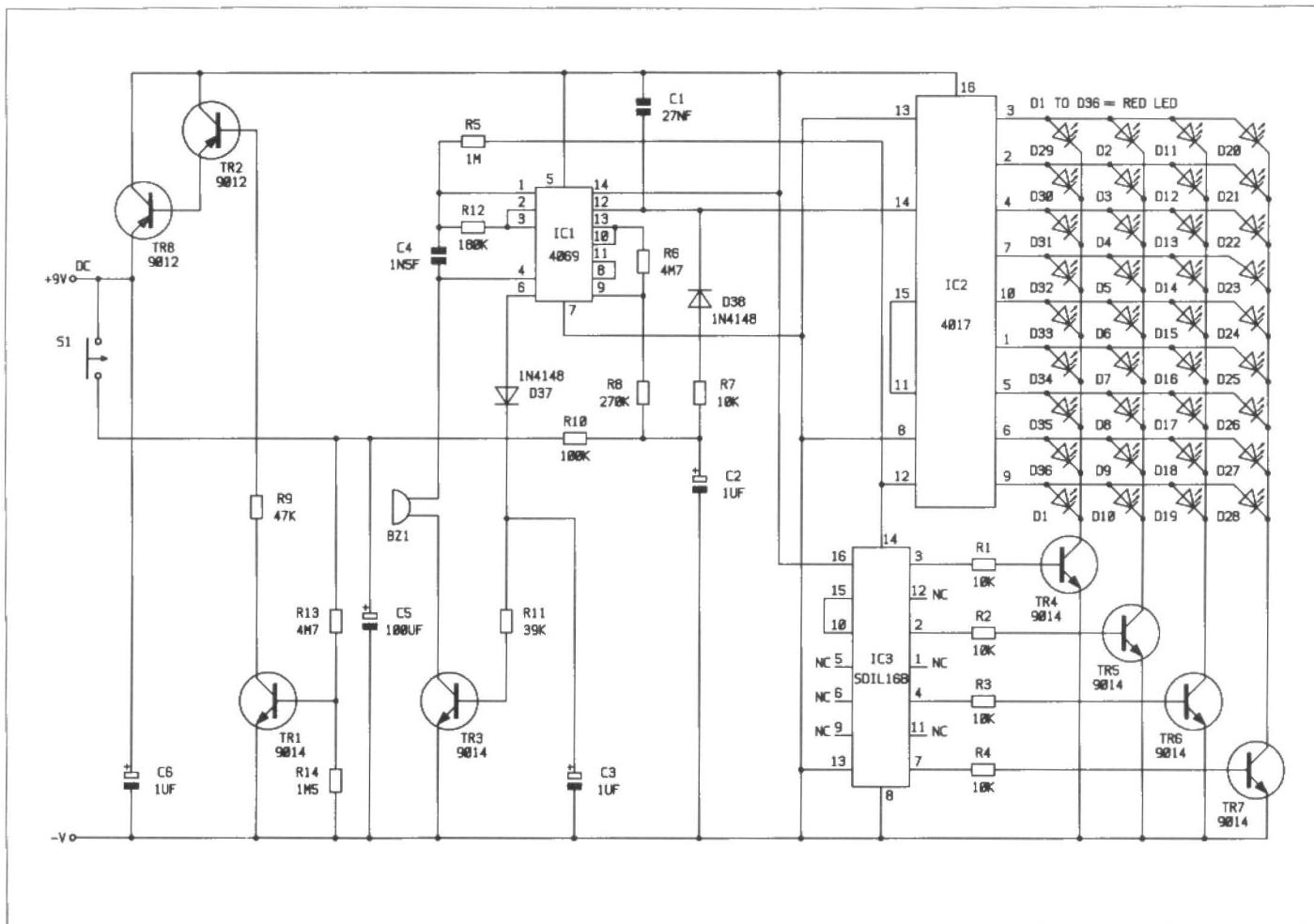
**Close-up of the electronics.**

'TY47' has only 36 numbers instead of the usual 37 because 0 has been omitted; however, although this can have an effect on the way the game is played, it does not pose a major problem when playing the game just for fun. Of course, the 'TY47' is intended to be used purely for the enjoyment of playing the game and is not in any way proposed for use in serious gambling. I think that one of the most

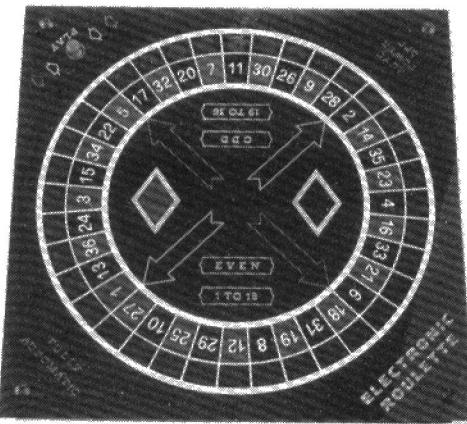
exciting things about playing this type of roulette is that you can gamble away as much pretend money as you like without spending any real money at all!

Roulette is based on the probability of the ball stopping on a number or series of numbers that have been previously picked by the player. In my experience the 'TY47' produces relatively random results and does not appear to follow any set

sequence. The game can be played by simply guessing which number the 'ball' will stop on, but I think that for full enjoyment it is well worth learning some of the rules and systems of betting. A full description of how to play roulette is outside the scope of this review; however, I thought it would be useful to include a few ideas to help the first time player. There are several systems of betting used when playing roulette and all of these have been devised to increase the probability of winning. In one system, known as 'Biarritz', a bet is placed on a number when it has not appeared for 11 spins of the wheel; the number is then backed until it appears. The amount that is bet is then doubled for each of the next 36 spins where the chosen number does not appear. I found it interesting to experiment with variations of the biarritz system, using a different number of spins; this can be intriguing, especially as the 'TY47' has only 36 numbers, instead of the usual 37. Another system of betting is called 'column and black'; this is a bet on the right most column of the roulette table (which contains 8 red numbers) and on all black numbers. As an alternative to using the established systems of betting, it can be fun to invent your own methods. I was surprised at just how effective even simple betting systems can be, although winning is still, of course, very much a matter of chance.



**Circuit diagram.**



Decorative front panel.

## Conclusions

All in all, I think the 'TY47 Super Electronic Roulette' game is a very well thought out product. In particular, a lot of attention has been paid to the presentation of the finished item. I have very much enjoyed building and using the 'TY47' and hope that you will have a similar experience should you decide to purchase this product. Finally, I would like to thank Maplin Electronics for the use of the review sample.

## Air your views. Continued from page 2.

### Unbalanced View

Dear Sir,  
I have read 'Electronics' for several years and on occasions when letters have been published I read and accepted readers comments that the magazine was dominated by computer based articles. However, it seems 'Electronics' cannot strike a happy balance. Since then it has seen a steady shift until in the last year there has been a complete domination of audio- and radio-based features and projects.

In December, 'Electronics' will go bi-monthly. Isn't this a great opportunity to correct the balance and publish a wide range of electronic topics? With 50% more space per year, audio projects need not be cut out while keeping those more interested in computing happy also.

Yours faithfully,  
Chris Cottam, Leek, Staffordshire.

The biggest problem we always had with our computer projects was the computer manufacturers' endless upgrading and modifying of their products. A project which worked perfectly for months or years would suddenly cease to function quite correctly. The problem was always that the computer manufacturer had slightly changed his product. This meant having to buy every new minor variation of all kinds of computers to test projects for customers, which was both expensive and took up a lot of space.

Therefore our new policy is to develop projects which interface with the computer via an agreed protocol (e.g. RS232), and several new projects of this sort are in the pipeline for 1989.

### Radioactive Rubbish

Dear Sir,  
I am 16 and do electronics as a hobby. I

## SUPER ELECTRONIC ROULETTE PARTS LIST

### RESISTORS

R1-4,7	10k	TR2,8	9012
R5	1M	D1-36	5mm Red LED
R6,13	4M7	D37,38	1N4148
R8	270k	IC1	4069
R9	47k	IC2,3	4017
R10	100k		
R11	39k		
R12	180k		
R14	1M5		

### MISCELLANEOUS

Buzzer	Push Button Switch
Brass Column	
Battery Clip 9V	
14-pin DIL IC Socket	
16-pin DIL IC Socket (2 off)	
M3 Screw (4 off)	
M3 Mut (4 off)	
Plastic Front Cover	
Link Wire (1 Metre)	
P.C. Board	

The Sound Master 'Super Electronic Roulette' kit is available from Maplin:  
Order Code LM67X Price £14.95

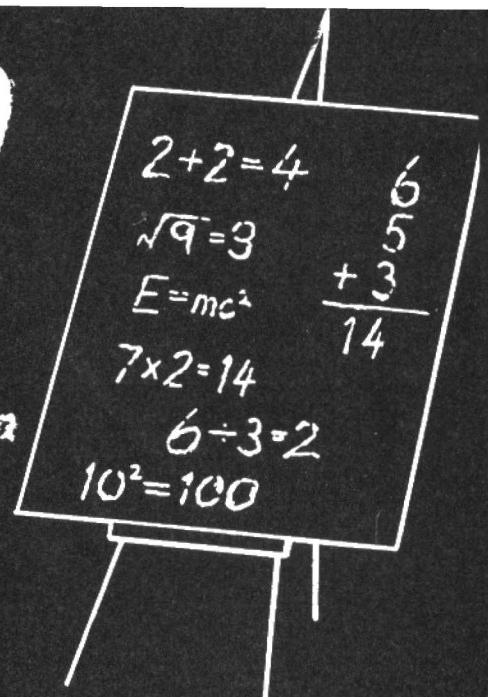
## MAPLIN'S TOP TWENTY KITS

THIS LAST MONTH	DESCRIPTION OF KIT	ORDER CODE	KIT PRICE	DETAILS IN PROJECT BOOK
1. (1)	• Digital Watch	FS18U	£2.00	Catalogue
2. (2)	• Live Wire Detector	LK63T	£3.95	14 (XA14Q)
3. (-)	• Siren Sound Generator	LM42V	£3.95	26 (XA26D)
4. (4)	• 160W Mosfet Amplifier	LW51F	£19.95	Best of E&MM
5. (3)	• I/R Prox. Detector	LM13P	£9.95	20 (XA20W)
6. (6)	• Partylite	LW93B	£9.95	Best of E&MM
7. (5)	• U/Sonic Car Alarm	LK75S	£17.95	15 (XA15R)
8. (-)	• Car Battery Monitor	LK42V	£6.95	Best of E&MM
9. (8)	• PWM Motor Driver	LK54J	£9.95	12 (XA12N)
10. (7)	• Car Burglar Alarm	LW78K	£7.95	4 (XA04E)
11. (9)	• Ultrasonic Intruder Detector	LW83E	£11.95	4 (XA04E)
12. (13)	• 27MHz Receiver	LK56L	£8.95	13 (XA13P)
13. (10)	• 8W Amplifier	LW36P	£5.95	Catalogue
14. (11)	• 15W Amplifier	YQ43W	£6.50	Catalogue
15. (-)	• Slow Charger	LM39N	£5.95	25 (XA25C)
16. (17)	• 27MHz Transmitter	LK55K	£7.95	13 (XA13P)
17. (15)	• Noise Gate	LK43W	£9.95	Best of E&MM
18. (16)	• 50W Amplifier	LW35Q	£17.95	Catalogue
19. (20)	• TDA7000 Radio Kit	LK32K	£12.95	9 (XA09K)
20. (14)	• Car Digital Tacho	LK79L	£19.95	Best of E&MM

Over 150 other kits also available. All kits supplied with instructions.

The descriptions above are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate Project Book mentioned in the list above - see inside back cover for details.

# CALC



by Jeff Scott Part 2

A nineteenth century mathematician, George Boole, invented Boolean algebra. What started as a mathematical exercise in logic is now essential reading for all those involved in the design of digital logic circuits.

## AND Logic

Boolean algebra expresses everyday logic like AND and OR in mathematical terms. For instance, if two outputs A and B must be present in order to produce an output S, then this is expressed mathematically as  $A \cdot B = S$ . The dot expresses AND. If the inputs are represented by switches then two states are provided by each switch. Switch closed will mean that the input is present at the decision gate, Figure 1, and switch open means that the input is not getting to the decision gate.

If a closed switch is represented by 1 and an open switch by 0, then all the combinations of A and B can be applied to the decision gate, see Figure 2. Such an exercise is called a truth table and represents all possible combinations of inputs. We can now write a truth table for any number of inputs, see Figure 3. This says quite simply that an output is present only when all the inputs are present.

## OR Logic

OR logic expresses the fact that an output is present if one or more inputs are present at the logic OR gate, Figure 4. The truth table for a two input logic OR is shown in Figure 5. We can now write the truth table for logic OR employing any number of inputs, see Figure 6.

Both AND logic and OR logic is combined in industrial applications. This is essential for full flexibility. Consider a lift operating between the floors of a building. The AND gate application could be illustrated by stating that the lift will move only if the doors are closed AND a floor select button is pressed, see Figure 7.

The same control box will contain OR logic for other purposes. For instance if the 'door open' button is pressed in the inside, OR 'call lift' on the outside, then the lift remains stationary at that floor. In Boolean algebra, the OR logic is expressed;  $A + B = S$ . The plus not meaning addition, but OR. This is an unfortunate departure from our usual understanding of the symbol +.

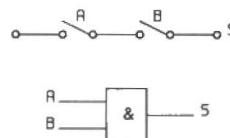


Figure 1. AND Gate.

A	B	S
0	0	0
0	1	0
1	0	0
1	1	1

Figure 2. AND Truth Table.

A	B	C	N	S
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	1	0	0	1
1	1	1	1	1

Figure 3. N input AND Table.

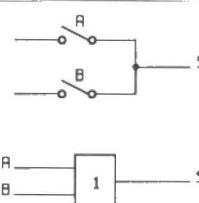


Figure 4. OR Gate.

A	B	S
0	0	0
0	1	1
1	0	1
1	1	1

Figure 5. OR Truth Table.

$$\begin{array}{r}
 2+2=4 \\
 \sqrt{9}=3 \\
 E=mc^2 \\
 7 \times 2=14 \\
 6 \div 3=2 \\
 10^2=100
 \end{array}$$

## Inversion

This is a simple mathematical concept. It merely says that the output is the opposite of the input. Therefore, a 1 at the input becomes a 0 at the output and a 0 at the input becomes a 1 at the output. This is expressed in a general manner by saying that S becomes  $\bar{S}$ . The bar above the S means the inverse of S, see Figure 8. The reason for the inverter or NOT gate is to change the polarity of the input signal so that logic functions can be performed.

A	B	C	N	S
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	1	0	0	1
1	1	1	1	1

Figure 6. N Input OR Table.

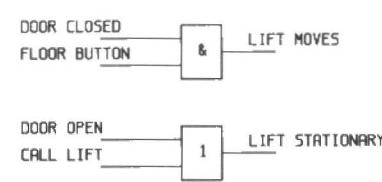


Figure 7. Illustrating lift control.



S	$\bar{S}$
1	0
0	1

Figure 8. Inversion.

## NAND Logic

NAND stands for Not AND. That is, the output of NAND logic will be the opposite of AND logic. From Figure 9, it can be seen that the output for NAND logic is the opposite of the input in Figure 2 for AND logic. The reason for this is that integrated circuits are cheap and all logic in a particular application is implemented using one kind of logic NAND or NOR.

It is easy to turn out thousands of gates on the same chip and leave it to the user to decide how to implement these, even if some are wasted in merely inverting the signal. Figure 10 shows a NAND used as an inverter. The general Boolean expression is  $\bar{A} \cdot \bar{B} = S$ , which says not A and B equals S. Note that  $A \cdot B$  is not the same as  $\bar{A} \cdot \bar{B}$  and is easily proved by the truth table shown in Figure 11.

## NOR Logic

Similarly, NOR stands for Not OR and all the outputs of the OR logic of Figure 5 are inverted, as shown in Figure 12. In Boolean algebra this is expressed  $\bar{A} + \bar{B} = S$ . The quantity under the bar  $\bar{A} + \bar{B}$  must be calculated first and then inverted, since  $\bar{A} + \bar{B}$  is not equal to  $\bar{A} + \bar{B}$ . Once again, it is easiest to prove this by writing the truth table for each, see Figure 13.

## EXCLUSIVE – OR Logic

This is another instance where an exercise in logic and mathematics now has important uses in electronic engineering. The logic states that if there are two inputs A and B, an output is produced only when one of them is in the ON state. There is no output when both inputs are ON or both inputs are OFF, see Figure 14. This is represented by  $A \oplus B = S$  in Boolean algebra and has important applications in error checking and in random generators.

## Boolean Algebra

The foregoing findings can be expressed in general terms using letters A,B,C, etc., where each of these letters can represent 1 or 0. Some of the AND logic can be summarised as:

Equation

$$A \cdot 0 = 0 \quad (1)$$

$$A \cdot 1 = A \quad (2)$$

$$A \cdot \bar{A} = 0 \quad (3)$$

$$A \cdot A = A \quad (4)$$

$$A \cdot B = B \cdot A \quad (5)$$

$$A \cdot B \cdot C = A \cdot (B \cdot C) = (A \cdot B) \cdot C \quad (6)$$

We can check equation (1) by substituting  $A=1$ , then 1 AND 0 is 0. And if  $A=0$ , the result is 0. Similarly, with equation (2), the result will be 0 if  $A=0$  and 1 if  $A=1$ .

Equation (3) is saying that 1 AND 0 is 0 or 0 AND 1 is 0, remembering that A is the opposite of  $\bar{A}$ . Equation (4) can be proved similarly.

Equation (5) is saying that we can AND two values in any order, or three values in any order, equation (6).

Let us now examine some generalised expressions for OR logic remembering that the + sign stands for OR.

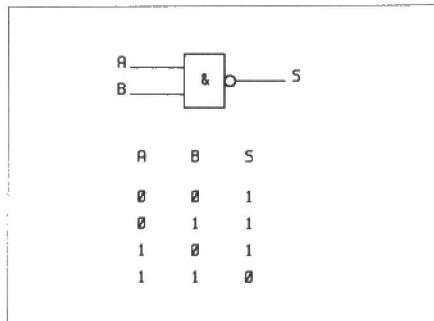


Figure 9. NAND Logic.

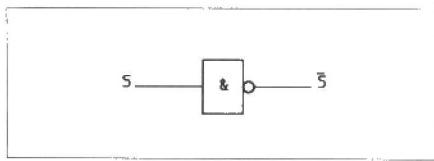


Figure 10. NAND as Inverter.

A	B	$A \cdot B$	$\bar{A} \cdot \bar{B}$	$\bar{A}$	$\bar{B}$	$\bar{A} \cdot \bar{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	0
1	0	0	1	0	1	0
1	1	1	0	0	0	0

Figure 11. To prove  $\bar{A} \cdot \bar{B} \neq \bar{A} \cdot B$ .

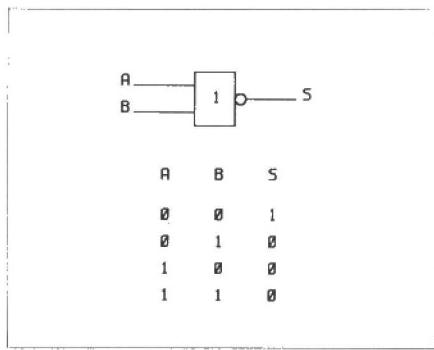


Figure 12. NOR Logic.

A	B	$A + B$	$\bar{A} + \bar{B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

A	B	$\bar{A}$	$\bar{B}$	$\bar{A} + \bar{B}$
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

Figure 13. To prove  $\bar{A} + \bar{B} \neq \bar{A} + B$ .

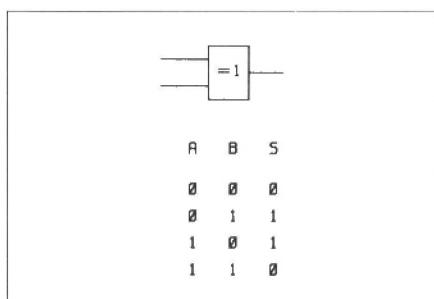


Figure 14. Exclusive OR.

Equation

$$A+1=1 \quad (7)$$

$$A+0=A \quad (8)$$

$$A+\bar{A}=1 \quad (9)$$

$$A+A=A \quad (10)$$

$$A+B=B+A \quad (11)$$

Equation (7) shows that the output will be 1 regardless of whether  $A=1$  or 0 whereas the output of equation (8) will depend on the value of A.

Equation (9) will have an output of 1 because one of the inputs is bound to be 1. Equation (10) will be 1 or 0 depending on whether A is 1 or 0 and equation (11) is saying that we can combine the variables in any order.

Let us now look at slightly more complicated cases employing both AND logic and OR logic. This is quite possible in factory processes even though one may finally implement the logic using one form only (NAND or NOR gates).

These are:

Equation

$$A+A \cdot B=A \quad (12)$$

$$A \cdot (A+B)=A \quad (13)$$

$$A+\bar{A} \cdot B=A+B \quad (14)$$

$$A \cdot (B+C)=A \cdot B+A \cdot C \quad (15)$$

$$A+B \cdot C=(A+B) \cdot (A+C) \quad (16)$$

Equation (12) can easily be proved by the truth table of Figure 15 and it can be seen that the first and last columns are equal.

Similarly, equation (13) is proved by the truth table of Figure 16, comparing the first and last columns.

Equation (14) is proved by the truth table of Figure 17 where it can be seen that the last two columns are similar. If equation (16) is correct then the left hand side of equation (14) can be expanded into  $(A+\bar{A}) \cdot (A+B)$ . Now from equation (9)  $A+\bar{A}=1$ , leaving  $A+B$  which is the same as the right hand side of equation (14).

A	B	$A+B$	$\bar{A}+B$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

A	B	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

Figure 15. To prove  $A+A \cdot B=A$ .

Equation (15) is saying that the left hand side can be expanded in the same way as any algebraic expression and is proved by the truth table of Figure 18.

The left hand side of equation (16) does not follow the normal factorisation rules of algebra. However, if we expand the right hand side, we get:

$$A \cdot A + A \cdot C + A \cdot B + A \cdot C$$

Now  $A \cdot A = A$  from equation (4), so this becomes:

$$A + A \cdot C + A \cdot B + B \cdot C$$

Factorising the first three terms

$$A(1 + C + B) + B \cdot C$$

The bracketed term becomes 1 since B, C can have values of either 1 or 0 and the equation reduces to:

$$A + B \cdot C \text{ which is the left hand side.}$$

As a check, Figure 19 proves this by means of a truth table.

Before we leave Boolean algebra, a simple statement must be added:

$$\bar{\bar{A}} = A$$

This says that if we invert a value twice we end up with the original value.

## De Morgans Theorems

Equation

$$\overline{A \cdot B \cdot C} = \bar{A} + \bar{B} + \bar{C} \quad (17)$$

$$\overline{A + B + C} = \bar{A} \cdot \bar{B} \cdot \bar{C} \quad (18)$$

It may not be obvious, but these two very useful theorems are used for converting NAND into NOR and NOR into NAND. If only NOR logic is available, then equation (17) is used to convert all the NAND expressions. If only NAND logic is available then equation (18) is used to convert all the NOR expressions.

For instance, to convert the following:

$$\overline{A + B} \cdot \overline{A + C} + \overline{B + C}$$

Applying equation (18):

$$\overline{A \cdot \bar{B} \cdot \bar{C} + \bar{B} \cdot \bar{C}}$$

There is one more OR sign to get rid of, therefore inverting twice does not change the expression.

$$\overline{A \cdot \bar{B} \cdot \bar{C} + \bar{B} \cdot \bar{C}}$$

$$\overline{A \cdot \bar{B} \cdot \bar{C} \cdot \bar{B} \cdot \bar{C}}$$

There appears to be plenty of seemingly unnecessary inversion but this is cheaper than using both NAND and NOR logic on the same chip.

The factory manager will state his complicated requirements which the mathematician will express in Boolean algebra as above. The engineer will then convert the maths into hardware but as we are only concerned with the mathematics here we shall not concern ourselves with the circuits.

It remains for us to prove 'de Morgan's theorems' and this is done most easily by means of a truth table. For simplicity, only two variables are considered and Figure 20 proves equation (17) and Figure 21 proves equation (18).

A	B	$A + B$	$A \cdot (A + B)$
0	0	0	0
0	1	1	0
1	0	1	1
1	1	1	1

Figure 16. To prove  $A \cdot (A + B) = A$ .

A	B	$\bar{A}$	$\bar{A} \cdot B$	$A + \bar{A} \cdot B$	$A + B$
0	0	1	0	0	0
0	1	1	1	1	1
1	0	0	0	1	1
1	1	0	0	1	1

Figure 17. To prove  $A + \bar{A} \cdot B = A + B$ .

A	B	C	$B + C$	$A \cdot B$	$A \cdot C$	$A \cdot B + A \cdot C$	$A \cdot (B + C)$
0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	0	0	0	0
1	0	0	0	0	0	0	0
1	0	1	1	0	1	1	1
1	1	0	1	1	0	1	1
1	1	1	1	1	1	1	1

Figure 18. To prove  $A \cdot (B + C) = A \cdot B + A \cdot C$ .

A	B	C	$B \cdot C$	$A + B$	$A + C$	$A + B \cdot C$	$(A + B) \cdot (A + C)$
0	0	0	0	0	0	0	0
0	0	1	0	0	1	0	0
0	1	0	0	1	0	0	0
0	1	1	1	1	1	1	1
1	0	0	0	1	1	1	1
1	0	1	0	1	1	1	1
1	1	0	0	1	1	1	1
1	1	1	1	1	1	1	1

Figure 19. To prove  $A + B \cdot C = (A + B) \cdot (A + C)$ .

A	B	$A \cdot B$	$\bar{A} \cdot \bar{B}$	$\bar{A}$	$\bar{B}$	$\bar{A} + \bar{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

Figure 20. To prove  $\bar{A} \cdot \bar{B} = \bar{A} + \bar{B}$ .

A	B	$\bar{A}$	$\bar{B}$	$\bar{A} \cdot \bar{B}$	$A + B$	$\bar{A} + \bar{B}$
0	0	1	1	1	0	1
0	1	1	0	0	1	0
1	0	0	1	0	1	0
1	1	0	0	0	1	0

Figure 21. To prove  $\bar{A} + \bar{B} = \bar{A} \cdot \bar{B}$ .

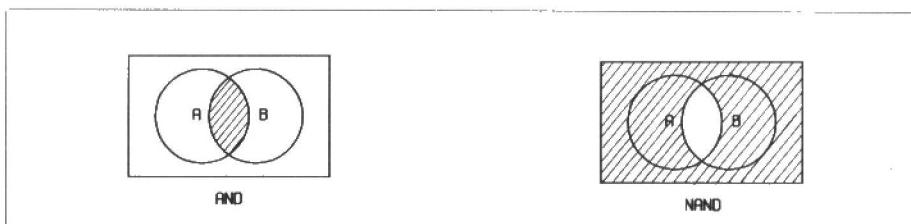


Figure 22. Venn diagrams for AND and NAND.

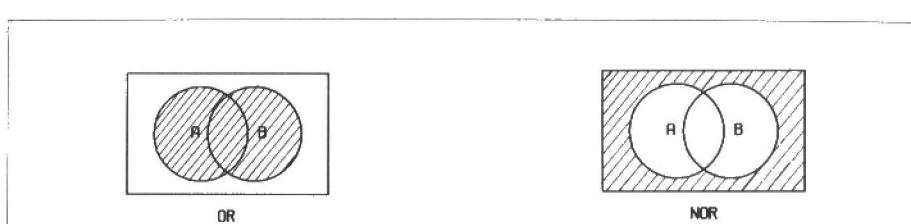


Figure 23. Venn diagrams for OR and NOR.

## Venn Representation

It is sometimes easier to grasp a concept when it is in pictorial form. Venn diagrams do just that, and Figure 22 shows the pictorial representation of AND and NAND. Figure 23 illustrates OR and NOR. These diagrams are for two variables and the diagrams get more intricate the more the variables.

## Karnaugh Maps

A complicated Boolean expression can be simplified in one of two ways; by applying the Boolean rules above or by using Karnaugh maps. The maps or tables are named after the inventor, just as Venn diagrams are named after their inventor.

A two variable Karnaugh map is shown in Figure 24 and the position of each of the combinations of A and B is shown. For example, if there is an output only when A and B are both present then a 1 is placed on that position on the map, Figure 25, and zeroes in all the other positions.

A Karnaugh map to cope with 3 variables is shown in Figure 26. Now suppose we have a factory process having outputs as shown in the truth tables of Figure 27, these can be transferred to the Karnaugh map of Figure 28.

In order to simplify the expression for the output, the ones are grouped as follows:

- All the ones must be included.
- The largest groups must be formed.
- The smallest number of groups must be aimed for.
- In forming the smallest number of groups, a one may be included again.

From the table of Figure 27 there is an output when  $\bar{A} \cdot B \cdot C + A \cdot \bar{B} \cdot \bar{C} + A \cdot B \cdot \bar{C} + A \cdot \bar{B} \cdot C$ . This is simplified using the above rules by making two groups to include all the ones.

In the top group, both B and  $\bar{B}$  are present, so we can ignore it, simplifying the top group to  $A \cdot \bar{C}$ . In the bottom group both A and  $\bar{A}$  are present so we ignore it and the bottom group becomes  $B \cdot C$ . Therefore, the result is  $A \cdot \bar{C} + B \cdot C$ .

As a check, let us simplify the expression using Boolean algebra.

$$\bar{A} \cdot B \cdot C + A \cdot \bar{B} \cdot \bar{C} + A \cdot B \cdot \bar{C} + A \cdot \bar{B} \cdot C$$

Taking  $A \cdot \bar{C}$  as the common factors of the two middle terms and factorising.

$$A \cdot \bar{C} (\bar{B} + B)$$

Now we know that  $\bar{B} + B = 1$ , so this reduces to  $A \cdot \bar{C}$ .

Similarly, factorising the first and last terms using  $B \cdot C$  as a common factor we get:

$$B \cdot C (\bar{A} + A)$$

Again  $\bar{A} + A = 1$  and this reduces to  $B \cdot C$  making the final result:

$$A \cdot \bar{C} + B \cdot C$$

Karnaugh maps are a powerful tool and in theory can be extended to any number of variables. In practice, the grouping becomes more complicated. Figure 29 shows a 4 variable Karnaugh map. The sides can be included in one group if one imagines the map as three dimensional and therefore folded over.

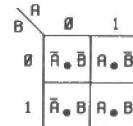


Figure 24. 2 variable Karnaugh map.

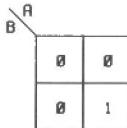


Figure 25. 2 variable Karnaugh showing AND.

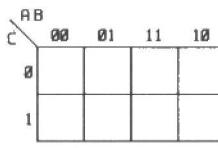


Figure 26. 3 variable Karnaugh map.

A	B	C	OUTPUT
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	1

Figure 27. Truth Table for Karnaugh map of Figure 28.

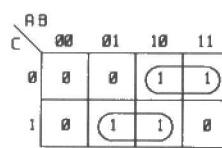


Figure 28. Karnaugh map for Truth Table of Figure 27.

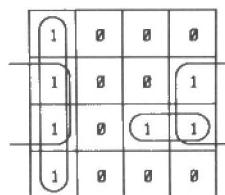


Figure 29. 4 variable Karnaugh showing side groupings.

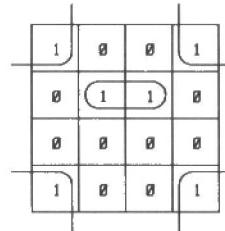


Figure 30. 4 variable Karnaugh showing corner groupings.

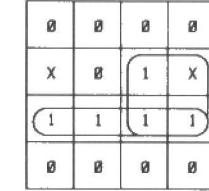


Figure 31. Karnaugh map showing 'don't care' conditions.

Similarly, in Figure 30, the ones in the corners belong to the same group since one can go off the top edge and reappear at the bottom of the screen.

Don't care conditions represented by an X can be used to increase the size of a group, see Figure 31. The don't care condition can be considered a 1 or zero depending on convenience. Figure 31 shows an X included in one group to form a larger group but the other X is treated as a zero and ignored.

The don't care condition requires explanation. For instance, a factory process may require a minimum of 6ml of paint sprayed on one item. Also the maximum quantity of paint may be required to be not greater than 10ml. If A=6ml and B=10ml then A and B cannot exist at the same time, that is A=1 and B=1 is not possible at the same time. We call these don't care or unspecified states and mark the Karnaugh map with an X.

That's all for now. See you in the next issue!

# ELECTRONICS

BY

# EXPERIMENT

Part 5 by Graham Dixey C.Eng., M.I.E.R.E.

## Introduction

The previous four parts of this series have been a mixture of theory and practice, with some accent on the theory in order to lay the necessary foundations for a good understanding of digital electronics. Anyone, who has wired up and tested all of the suggested circuits so far, should now be feeling fairly confident about the uses of gates and flip-flops. What follows will apply some of these acquired skills before introducing a few, new and important devices and circuits.

## Multiplexing and Demultiplexing

Taking these terms in order, multiplexing is a technique by means of which a number of quite separate signals share a common path. This 'sharing' may be achieved by using different carrier frequencies for the signals, a method known as 'frequency division multiplex' (f.d.m.), or by allocating them to given 'time slots', this being known as 'time division multiplex' (t.d.m.). The former method is the basis of carrier telephony and does not concern us further; the latter has very useful practical applications and will now be discussed at length.

Figure 1 illustrates, very simply, the idea behind the multiplexing of four digital signals A, B, C and D and each must, for 'one quarter of the total time' be connected to its own display DY<sub>A</sub>, DY<sub>B</sub>, DY<sub>C</sub> or DY<sub>D</sub>. In this analogy switches are used at each end of the signal path and all that is necessary is to ensure that both switches operate together, that is in synchronism. To take an example, when SW1 connects signal A to the bus, SW2 must then connect display DY<sub>A</sub> to the receiving end of the bus. Both switches thus operate together at some particular speed. Obviously this is not a practical system, not the least because the signals are 7-bit digital signals, required to drive the 7-segment displays, implying that both SW1 and SW2 are 7-pole switches! With this simple understanding of multiplexing we can now move on to the more practical arrangement of Figure 2.

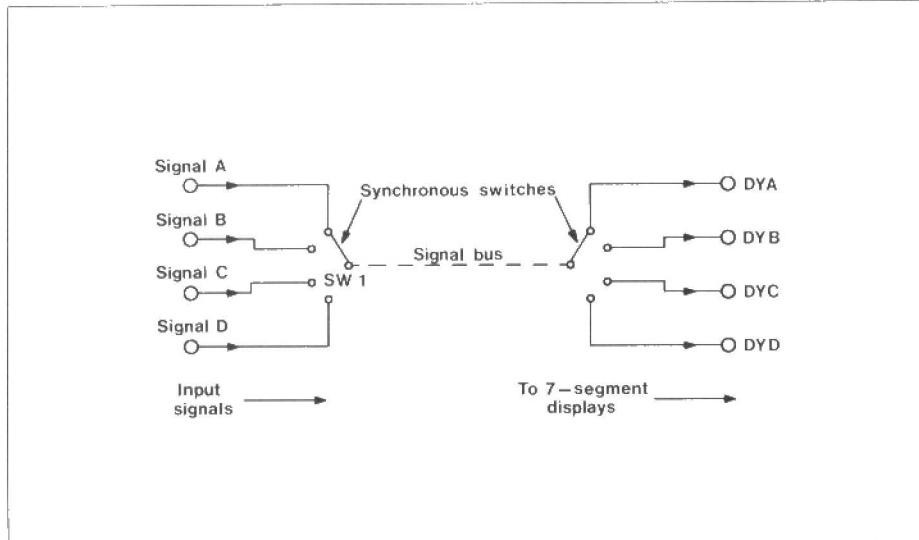


Figure 1. Multiplexing four digital signals to four 7-segment displays.

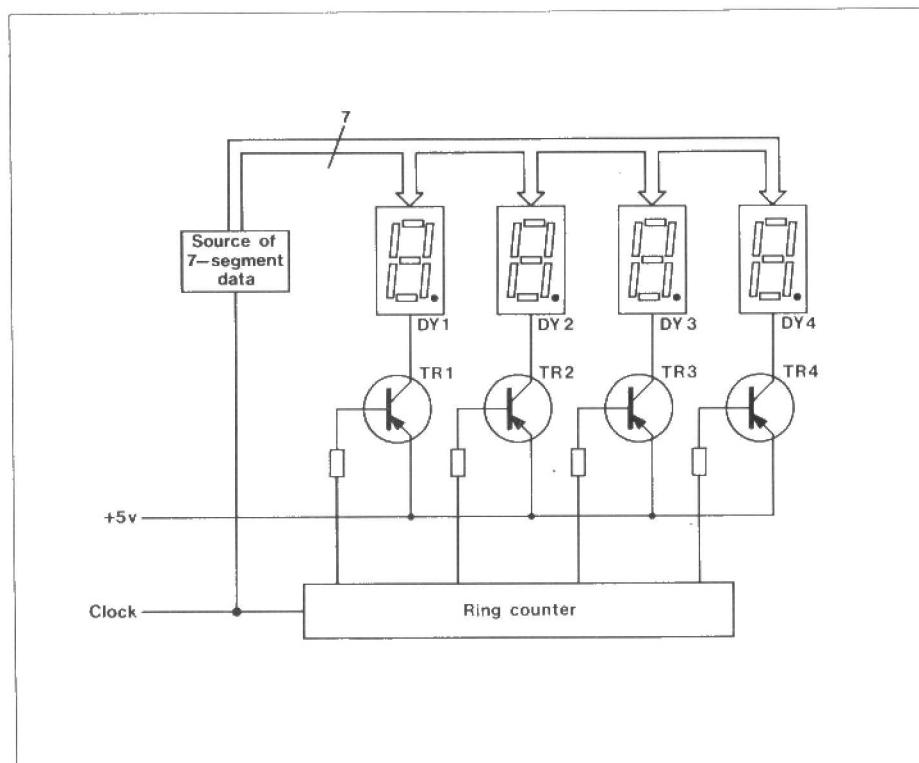


Figure 2. Multiplexing 7-segment displays using a Ring Counter.

At first sight it may be difficult to relate this diagram to the ideas of Figure 1. This is because the actual signals A-D are no longer individually identified and the switching is quite different. Let us look at the switching first.

A ring counter is used in which only one of its flip-flops is cleared ( $Q = 0$ ), the other flip-flops being set ( $Q = 1$ ). When this ring counter is driven from some clock source, the solitary 'zero' will pass from one flip-flop to the next one to its right and, when it reaches the output of the last flip-flop in the chain, it will be fed back to the input of the first flip-flop, a process that continues indefinitely. The circulating zero is applied sequentially to the bases of the transistors TR1-TR4, switching each on in turn (note that the transistors are PNP types) as it appears at its base input. Any transistor that is switched on in this way offers a conducting path, for any display segment that requires it, to the +5V line. The actual segments lit on the selected display are determined by the hexadecimal code placed on the bus by the block marked 'Source of 7-segment Data'. Notice that this is connected to the same clock source so that the correct data may be on the bus when a particular display is selected.

The actual source of 7-segment data will include a BCD to 7-segment decoder,

such as a 7447, and a means of supplying the right data at the right instant of time. In a microprocessor controlled system this is quite easily achieved by using the system clock to control both the ring counter and the supply of data to the 7447. But to explore these ideas in practice on the bench, a simpler approach is required. This is provided by the circuit of Figure 3.

Starting with the 'scale-of-four binary counter', this generates at its Q outputs the binary sequence 00, 01, 10, 11 which repeats indefinitely. Note that because of the convention of showing the clock input on the left of the counter, the values at Q for each flip-flop appear reversed, that is the least significant bit (L.S.B.) is on the left. The four binary values shown are in fact the lowest two bits of the Binary Coded Decimal (B.C.D.) equivalents of the denary numbers 0, 1, 2 and 3. The 7447 decoder/driver IC will automatically convert these to the correct 7-segment codes so as to cause these digits to appear on the display. However, to avoid confusing the 7447, the highest two bits of the B.C.D. groups for 0, 1, 2 and 3 are also supplied by the simple expedient of wiring these chip pins to 0V. As a result, the actual inputs to this IC are 0000, 0001, 0010 and 0011, these being the full B.C.D. codes for the stated denary values. The 7447 now outputs the correct codes to the common-anode

displays, all of which have their segment pins connected in parallel. To limit the LED current to a safe value, 100 ohm resistors are connected in each line between the 7447 and the displays. Naturally, the fact that all 7447s receive the same data at the same time is of no importance; only that display enabled by the ring counter at that instant will actually display anything. As the ring counter moves on to the next display the data from the 7447 onto the segment lines changes to give the correct data for the newly selected display. Thus, at any instant, only one display is actually energised; the rest are blank. However, by multiplexing them at a high enough frequency (greater than about 25Hz) the human eye is deceived into seeing all the displays on at once!

The ring counter must be initialised so that only one Q output, the first, is at logic 0, the others being at logic 1. Also, the scale-of-four counter should start off with both flip-flops clear, otherwise the codes sent to the 7447 will be out of step with the display sequence. Provision for these initial conditions can be made with an automatic resetting circuit of the same type often used to initialise microprocessor ICs. This consists of an RC circuit, whose time constant is long enough to allow the counter flip-flops to respond, which charges up when power is first applied so

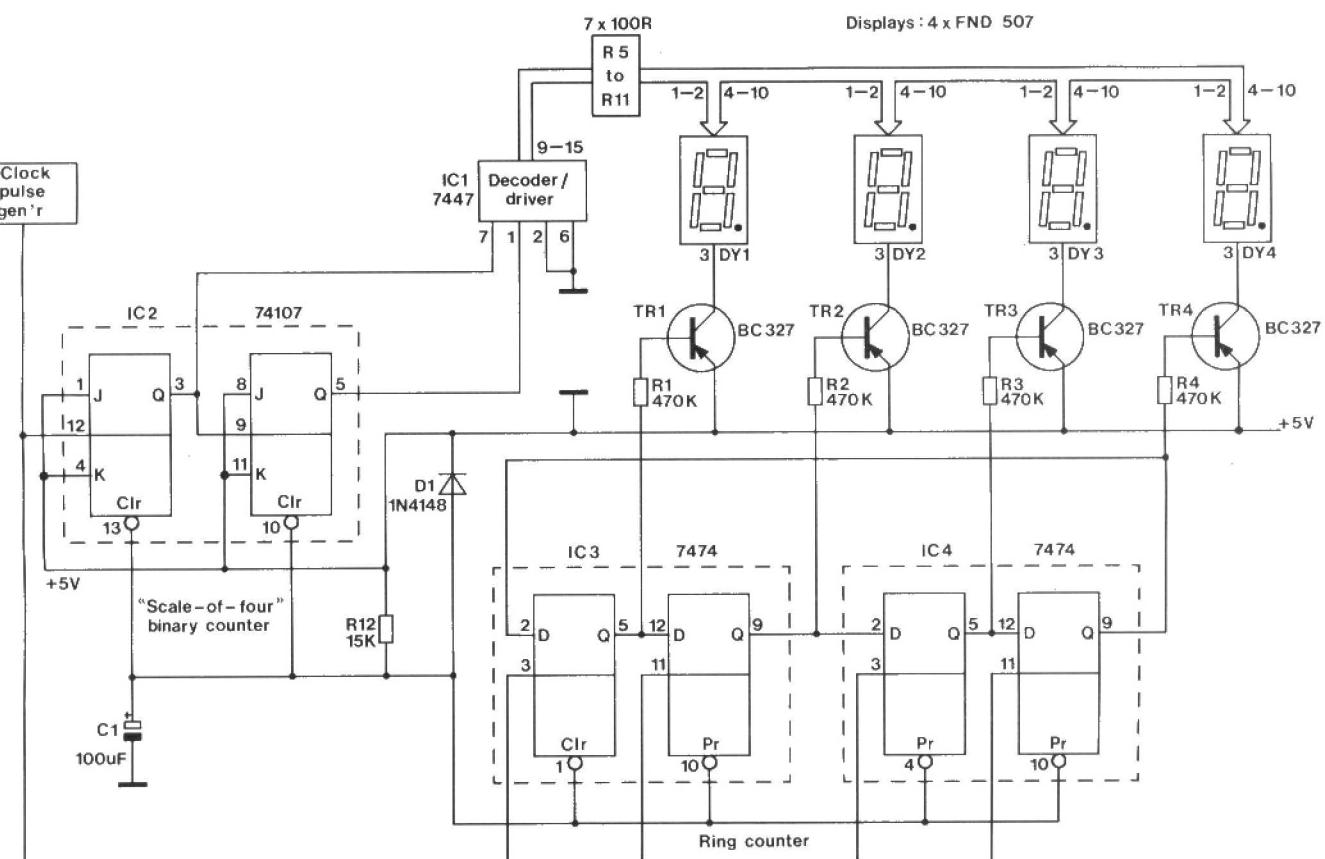


Figure 3. Circuit for demonstrating multiplexing of 7-segment displays using a Ring Counter.

that from an initial value of zero volts (clearing the flip-flops connected to it), the reset line rises to logic 1, allowing the counters to start operating.

All being well, when the circuit is switched on, the displays should show the numerals 0, 1, 2 and 3, reading from left to right. If a low multiplexing rate is used, the multiplexing action can be seen quite clearly. Setting the clock generator to 1Hz will achieve this. Connecting LED indicators to the Q outputs of the ring counter will show how the circulating zero enables each display in turn.

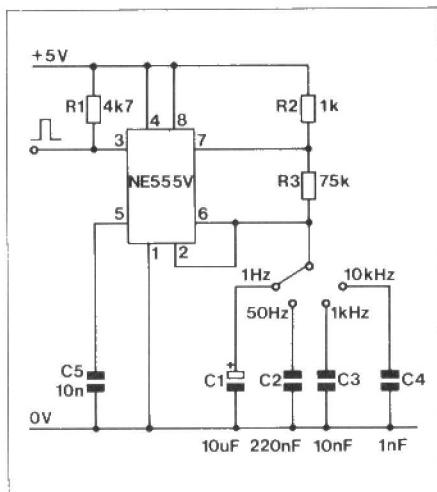


Figure 4. Switched frequency TTL clock pulse generator.

The clock pulse generator can be the 555 circuit described in Part 3. This is reproduced again here, in Figure 4, slightly modified to give a wider range of frequencies, selected by a rotary switch. The frequency of 50Hz has been included so that it can be demonstrated that, when this frequency is used to multiplex the displays, the result is a clear and flicker-free readout. As described previously, the 'persistence of vision' of the human eye will ensure this, using the same principle that allows us to see a complete and continuous television picture.

Since a pulse generator with several available frequencies is useful to include in one's test set-up, the circuit of Figure 4 has been put onto Veroboard and the layout of both sides of the circuit board are shown in Photos 1 and 2.

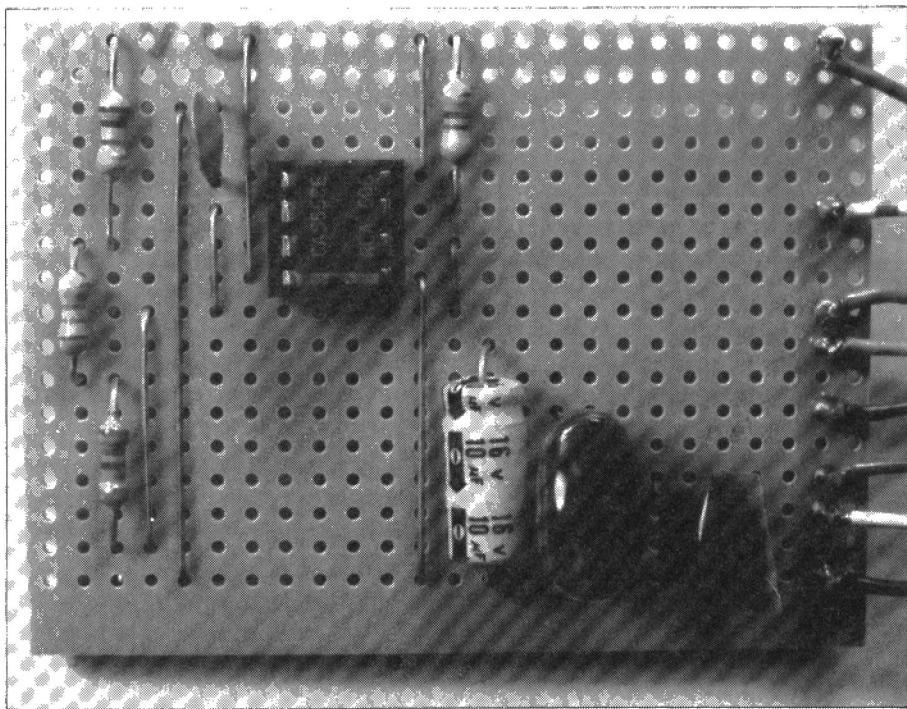


Photo 1. Pulse Generator - component side.

Demultiplexing is, as the name implies, the opposite of multiplexing. In fact, in the system of Figure 1, the switching circuit to the left of the signal bus is a multiplexer, while the circuit at the receiving end of the bus is a demultiplexer. From this it can be seen that the function of a multiplexer is to bring together signals from various sources onto a common line, while the function of a demultiplexer is to separate them out again, at the other end of

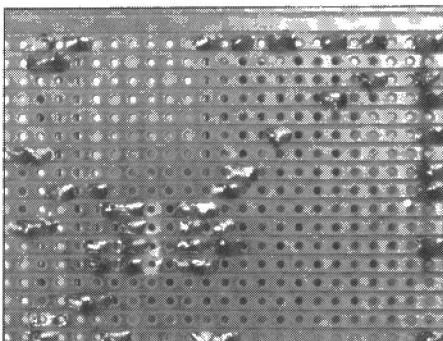


Photo 2. Pulse Generator - copper side.  
Note that the only track breaks required are between the pins of the IC.

the line, and route them to their correct destinations. This can be demonstrated with the help of the circuit of Figure 5. The procedure is as follows:

(a) Wire up the two chips as shown, but connect  $S_0$  to  $A_0$  and  $S_1$  to  $A_1$ . This synchronises the selection of inputs and outputs using the line.

(b) Connect logic level switches (four) to  $I_{0a}$  -  $I_{3a}$  (to set up the input signals) and two further logic level switches to  $S_0/A_0$  and  $S_1/A_1$ .

(c) Connect logic level indicators (four) to outputs  $O_a$  -  $3_a$ .

(d) Set all input levels to logic 0.

(e) Set the switches on  $S_0/A_0$  and  $S_1/A_1$  to the logical combinations 00, 01, 10 and 11 in turn and note that the LED indicators connected to  $O_a$  -  $3_a$  will only 'go down to zero', one line at a time. It is possible to record this in a truth table as follows:

$S_1/A_1$	$S_0/A_0$	$O_a$	$O_1$	$O_2$	$O_3$
0	0	0	1	1	1
0	1	1	0	1	1
1	0	1	1	0	1
1	1	1	1	1	0

Now, to make the exercise a little more interesting, remove the switches that are currently connected to  $S_1/A_1$  and  $S_0/A_0$  and replace them with the Q outputs of the clock driven 'scale-of-four counter' of Figure 3. This will automatically cycle through the four states, given by the first two columns of the truth table above, previously selected manually by the switches, now disconnected. With the clock generator set to a frequency of 1Hz, you can observe how the zero at the outputs appears at the same rate (assuming that the input switches are still all set at zero).

Finally, set up any random combination of these input switches and see how

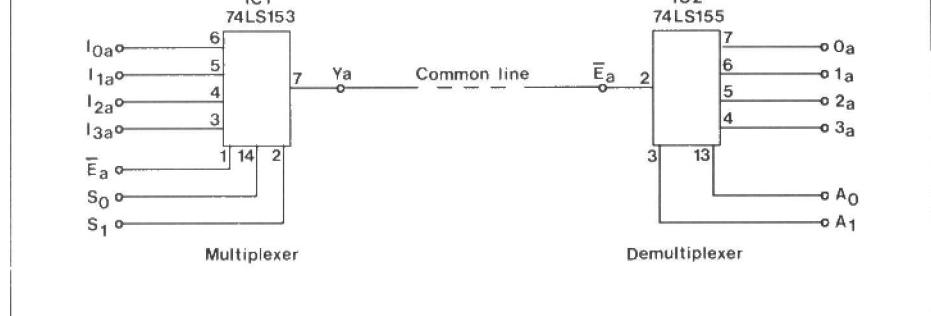


Figure 5. Multiplexing and demultiplexing four signals on a common line.

this same combinations of logic levels is reflected in the states of the LED indicators connected to the output lines. This is a clear indication of the basic principles of multiplexing and demultiplexing.

## Schmitt Trigger Circuit

This circuit, still very much in use today, has its roots well and truly in the days of valve technology – a statement that is true of many ‘modern’ circuits. All that has changed is the physical form. The Schmitt trigger action is found in the inputs of certain TTL gates, and may be implemented by using an ‘op-amp’ and can be easily demonstrated with a simple, discrete component circuit. The latter will be used now to study the basic action.

Figure 6 shows a discrete Schmitt trigger circuit, TR1 and TR2 and associated components forming the actual trigger circuit (left of chain line). Transistor TR3 is merely a lamp driver to show the output state of the Schmitt trigger circuit. It could be omitted and a voltmeter used instead, but it is probably more convenient to include it as a quick, visual check of circuit operation. The potentiometer RV1 is used to supply a variable d.c. level (the effective input to the circuit) to the base of TR1. Apart from a 9V d.c. supply to power the circuit, the only other piece of equipment necessary is a multimeter, which should be set to the 10V d.c. range.

Having connected up the circuit, RV1 should be set so that its wiper is at 0V (input to circuit equals zero). Now, when power is applied, it should be noted that the LED is not lit. If it is, switch off and check the circuit – including where the wiper of RV1 actually is! All being well, RV1 wiper should be rotated gradually and, at some point, the LED should suddenly come on. If it does then the circuit is working correctly. Rotating the wiper back towards 0V should cause the LED to go out again. Has anything been noted at this point?

Let us be more methodical about it. The voltmeter should be connected to the wiper of RV1 so that, as the wiper is rotated upwards from 0V, the actual input voltage is being continuously monitored. Now, as the LED suddenly comes on, the input voltage at which this occurs can be read from the voltmeter. This voltage can be called  $V_{ON}$ . Again, as the wiper is reversed in direction, the voltage at which the LED goes out again can also be read. This voltage can be called  $V_{OFF}$ . What should have been noticed is that the value of  $V_{OFF}$  is lower than that of  $V_{ON}$ .

The difference between these two voltages is known as the ‘backlash’ or ‘hysteresis’ of the circuit. It is an important characteristic of Schmitt trigger circuits.

The other important characteristic of these circuits is their ‘snap action’. The circuit is always just ON or OFF, never in between. It is quite impossible to catch the action halfway between the states, no matter how slowly the wiper is moved, as can be proved by trying it! This type of operation arises because of an inherent

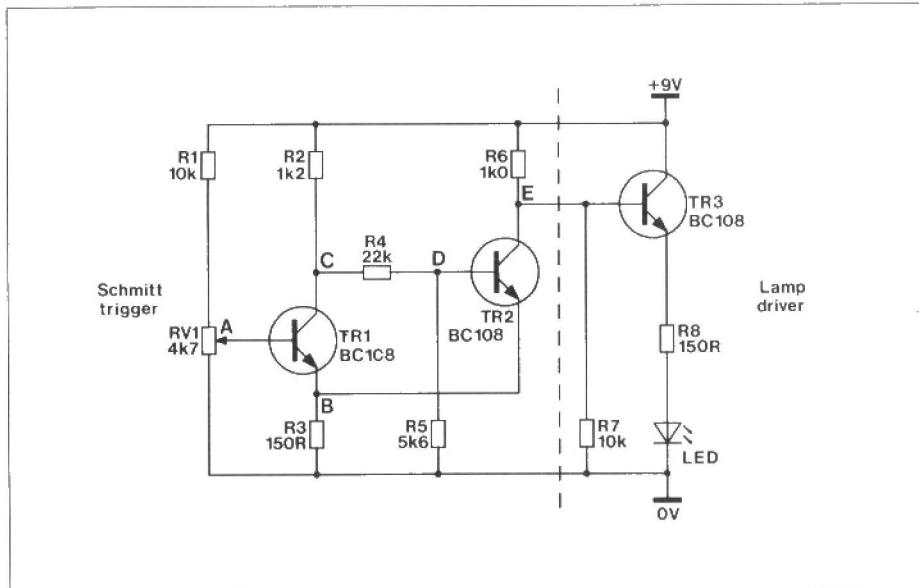


Figure 6. Discrete component Schmitt trigger circuit.

‘regenerative’ action, that can be explained as follows.

If, with the wiper of RV1 at 0V, the potentials of the test points B to E are measured, a typical set of results might be as follows:

B (+1.0V); C (+8.6V); D (+1.6V); E (+1.2V)

These results show that:

(a) TR1 is OFF at this time (as one would expect, since its base is at 0V) and TR2 is ON.

(b) TR2 is in ‘saturation’ since its collector-emitter voltage is a mere 0.2V (the difference between the voltages at test points E and B).

(c) The base-emitter potential of TR2 is 0.6V (difference between the voltages at test points D and B); this is important since it controls the conduction of TR2.

(d) Since TR2 is conducting, its collector potential is low (1.2V), so that TR3 is OFF and the LED is not lit.

Now we can consider what happens as the wiper of RV1 is rotated upwards from 0V.

(i) At first nothing happens simply because the input voltage has to approach a value of 1.6V before TR1 can even begin to conduct. Why is this? It is because, for a silicon transistor to conduct, its base-emitter voltage must approach 0.6V, and since the emitter of TR1 is already at 1.0V, the TOTAL voltage at the wiper has to be  $1.0 + 0.6 = 1.6V$ .

(ii) As the input voltage approaches 1.6V, TR1 begins to conduct; its collector current will slowly rise, causing an increasing volt drop across its collector load resistor R2. As a result, the collector potential will fall and, since this is coupled to the base of TR2, the base drive to TR2 will be reduced, causing the collector current of that transistor to start falling. Thus the collector currents of the two transistors TR1 and TR2 are now moving in opposite directions, one rising, the other falling.

(iii) The resistor R3 is common to the emitters of both TR1 and TR2 and the current through this tends to remain fairly

constant because of the inverse action of the currents in TR1 and TR2 explained in (ii) above. Thus, while the emitters of both TR1 and TR2 are held at a constant voltage, the base of TR1 is rising in potential while that of TR2 is falling.

(iv) What we now have is the beginning of the ‘regenerative’ action. To explain this word, it means simply an action that, once started, sustains itself. In this example, a moment’s thought should lead one to realise that the rising current in TR1 is the cause of the falling current in TR2, but the falling current in TR2 is allowing the emitter of TR1 to be held at a constant potential. As a result, the base-emitter voltage of TR1 is more effective than it would be otherwise. The more TR1 turns ON, the more TR2 turns OFF, and the more TR1 turns ON – and so on. The switching action is very fast and ends up with TR1 in saturation and TR2 cut off. Point E is now high in potential, TR3 turns ON and the LED is lit.

(v) A similar action occurs when the wiper of RV1 is reversed but what has to be explained is the ‘hysteresis’. This is quite easy, especially if we suppose that the wiper was left at the exact point at which the switching on action occurred. Because TR1 is in saturation its collector voltage is low. It must rise quite substantially before it can supply enough drive to the base of TR2 to cause the latter to start conducting again. The wiper of RV1 must, therefore, move well past (in a downward direction) the point at which the original switching occurred before a new switching action can be initiated. When it is, TR1 rapidly switches OFF again, TR2 switches ON, point E falls, TR3 turns OFF and the LED goes out.

## TTL Schmitt Trigger Circuits

It was mentioned earlier that certain TTL gates have Schmitt trigger inputs. An example of this is the 7414, which is a HEX Schmitt trigger inverter package. Each of the six individual inverters exhibits the

'snap action' that is a characteristic of these devices. As a result, the output snaps from one logic state to the other, no matter how slowly the input changes, once the trigger point (a specific input level) has been reached. In a standard TTL gate the rate of change of the output is the same as that of the input. Figure 7 illustrates this. This is very useful because it means that noise in the input signal is disregarded (unless it is exceptionally large in amplitude) and a slowly changing signal at the input of the device is converted to an output pulse with rapid rise and fall times. Thus, a pulse that has been 'degenerated' by circuit time constants can be 'regenerated' by its passage through a Schmitt trigger circuit. It is also possible to convert sinewaves (and other waveforms) into pulses. Figure 8 shows how the circuit switches on and off at those points in a waveform corresponding to the ON and OFF thresholds of the Schmitt trigger. What the waveform is doing at other times is of no importance whatever; the output of the Schmitt circuit merely switches backwards and forwards between its only two possible levels.

Figure 9(a) shows how a Schmitt trigger circuit can be constructed by using standard TTL inverters. This should not be confused with a TTL gate having a Schmitt input; the circuit of Figure 9(a) is merely the TTL equivalent of the discrete circuit of Figure 6. However, it is much simpler, just two gates from a 7404 HEX inverter and two resistors. It works best if it is fed from a low impedance source. It is a simple matter to hook this circuit up and check it out in a similar way to the testing of the previous discrete circuit. The thresholds should be found at around 0.7 and 0.95 volts. Two applications for this circuit can be seen in Figure 9(b) and (c). In Figure 9(b) the contact bounce of a single-pole switch is eliminated by following it with the Schmitt circuit. It is worth hooking up this circuit on the breadboard and finding out exactly what it does. Finally Figure 9(c) shows a common use for Schmitt trigger circuits, when it is used to convert the 50Hz mains (at low level) into a square-wave. This will also have a frequency of 50Hz, naturally, but its mark-space ratio will not be 1:1. This does not always matter. A practical application of this type of circuit is to derive the reference frequency to drive the counters in a digital clock. Counters do not work well with sine-wave inputs, hence the need for the conversion.

## The Monostable Circuit

The monostable is one of a class containing three circuits, known collectively as 'multivibrators'. The other two have already been met. They are the bistable (having two stable states), otherwise known as a flip-flop and used in sequential logic circuits, and the astable (no stable states - hence known as free-running). The former is usually found as D or JK types, the latter pops up in various guises, one of which is an application of the 555 timer IC.

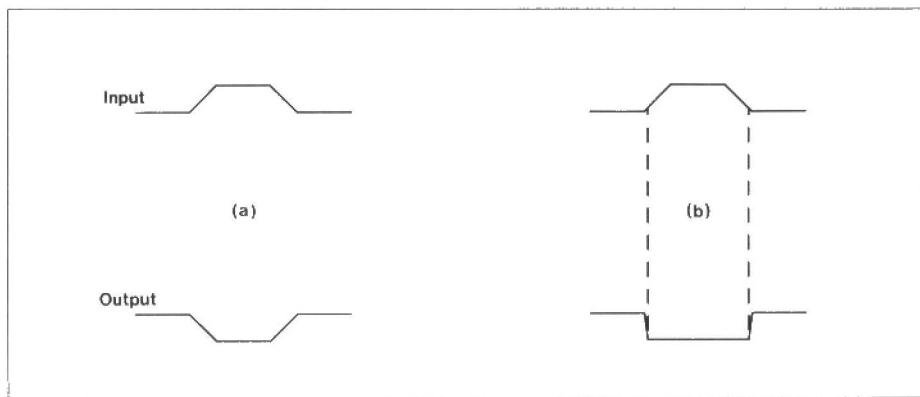


Figure 7. Action of (a) normal TTL inverter (b) Schmitt inverter.

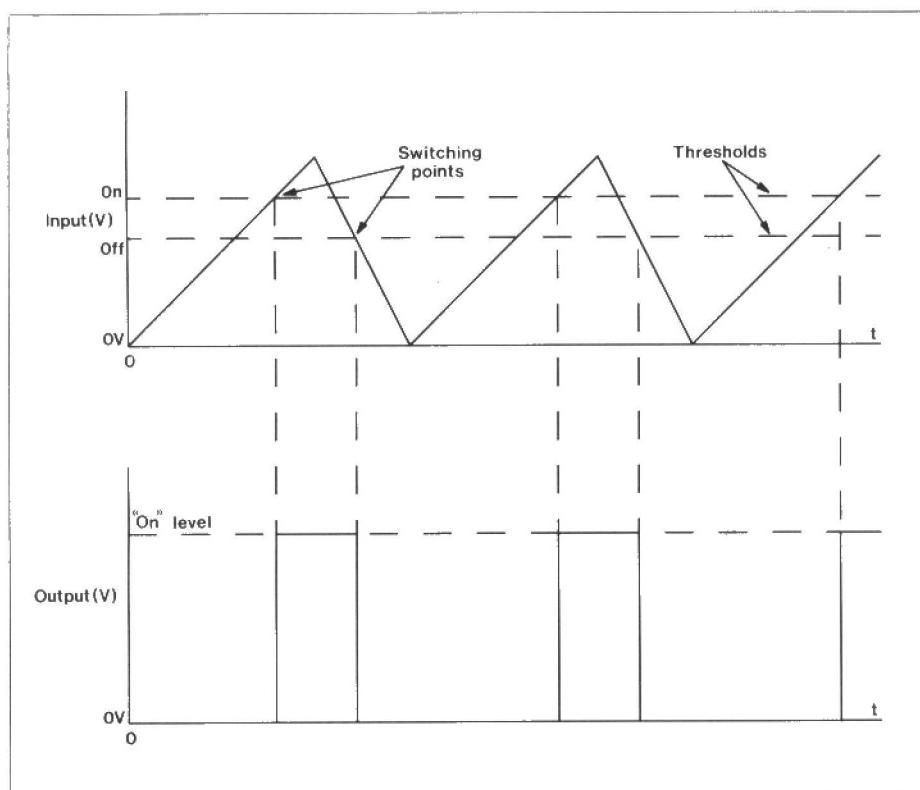


Figure 8. Showing how a Schmitt trigger circuit converts an alternating input to pulses.

These three circuits are called multivibrators because they are able to generate square waves, which are rich in harmonics.

The monostable is also often known as a 'one-shot' circuit because, on being triggered, it generates a single square pulse, of predetermined duration, and then waits to be triggered again. It is said to have one stable state - in which it normally rests - and a 'quasi-stable' state into which it goes only temporarily when it is triggered. The duration of the latter state is determined by an RC time constant. If it is continuously triggered it will generate a train of pulses. In general it is necessary to allow it to complete one cycle before retriggering. Except in a special case, to be discussed soon, the circuit will simply ignore any pulses during the 'quasi-stable' time.

It is possible to construct a monostable circuit from two transistors, a few resistors and a capacitor. However, this time we shall pass over the discrete approach and

go straight to an IC version, again using the ubiquitous 555 timer IC. The circuit is shown in Figure 10.

Again we have a very simple circuit, just one resistor and two capacitors and the IC itself. The calculation of the output pulse duration  $T_Q$  (the quasi-stable time) is easy since it is given by the relation:

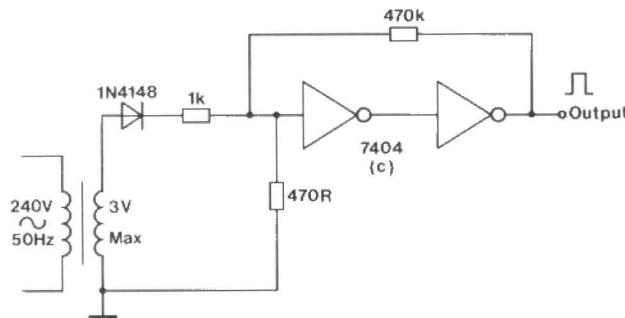
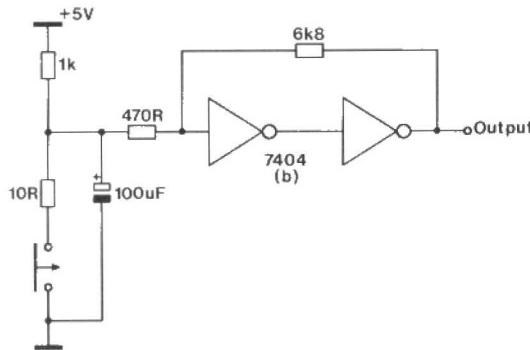
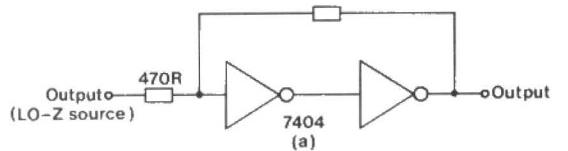
$$T_Q = 1.1RC$$

To take an example, if  $R = 10k$  and  $C = 100nF$ , then:

$$T_Q = 1.1 \times 10^4 \times 10^{-7} \\ = 1.1ms$$

The maximum triggering frequency in this case is just under 1kHz.

To try out this circuit it will be necessary to generate the negative triggering pulses. Figure 11 shows a simple way



**Figure 9.** TTL Schmitt triggers.

- Basic TTL Schmitt circuit.
- De-bouncing a single pole switch.
- Deriving square waves from 50Hz mains.

of converting the output of a square-wave generator (such as the 555 circuit built previously) into the required fast negative going pulse. An RC time constant differentiates the square wave to give a positive spike from the leading edge and a negative spike from the trailing edge; the two diodes form a clamping and clipping arrangement to eliminate the positive spike.

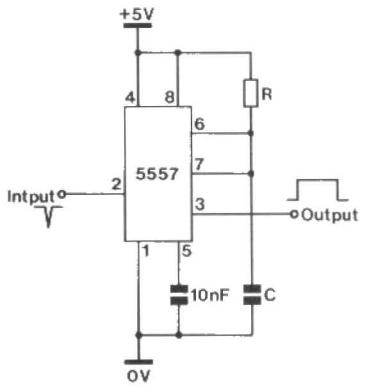
## Non-retriggerable and Retriggerable Monostables

The circuit of Figure 10 is actually a 'non-retriggerable' circuit. This means that, once it has been triggered, further trigger pulses will have no effect until the circuit has completed its cycle. It is possible to have a monostable circuit that is 'retriggerable', that is it can be triggered again during its cycle, and the timing period will

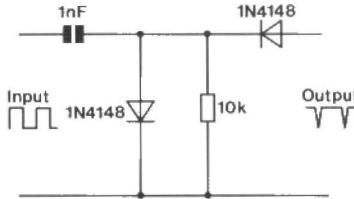
start all over again from the point at which it was retriggered. In fact the circuit of Figure 10 can be very readily converted to a retriggerable type, merely by connecting Pin 4 to Pin 2 instead of to the +5V supply rail. It is worth experimenting with these two modes but it will be necessary to choose a triggering frequency such that the time between pulses is less than the quasi-stable time. If a fairly high frequency is used it will be found that the output of the monostable is permanently high since it never gets the chance to complete one cycle before it is triggered again!

## TTL Monostables

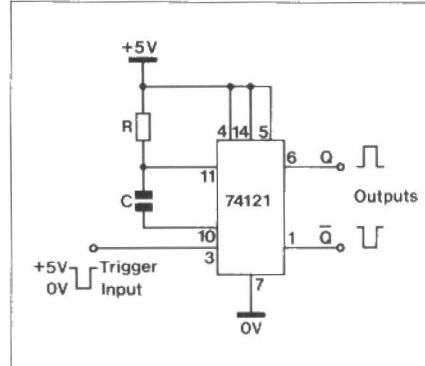
There are a number of TTL monostables, the best known being the 74121, 74122 and 74123 (dual) types. To round off this article, Figure 12 shows the arrangement for the 74121, which needs only the two timing components, R and C, as extras.



**Figure 10.** Monostable circuit using 555 timer.



**Figure 11.** Circuit for producing negative trigger pulses from a square wave source.

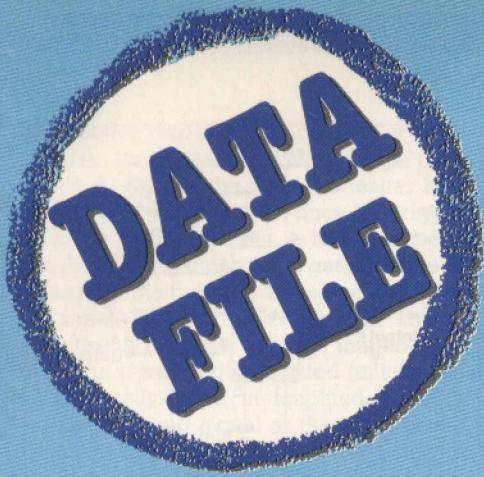


**Figure 12.** The 74121 TTL monostable.

The equation for the output pulse duration is as follows:

$$T_O = 0.7RC$$

The first five parts of this series have dealt exclusively with digital logic components and circuits. This has been for very good reasons. Digital techniques are increasing in their importance all the time; it is actually easier to get to grips with digital circuits, and the actual experiments are easier to set up and generally need less test equipment. However, the time has now come for a change and, with the next issue, we shall start experimenting with linear (analogue) circuits, kicking off with an in-depth look at that particularly useful component, the 'operational amplifier', or op-amp for short. In addition, the design of a suitable dual-rail power supply will be included for experimenting with op-amps. This can be built as a totally separate piece of test-gear or be made as an expansion for the power supply described in Part One. See you then.



# LM386 LOW VOLTAGE POWER AMP

## Features

- ★ PCB available
- ★ Suited to battery operation
- ★ Low quiescent current drain (6mA)
- ★ Broad supply voltage range (4V to 12V)
- ★ Minimum number of external parts

- ★ Adjustable voltage gain from 20 to 200
- ★ Ground referenced input
- ★ Low level of distortion
- ★ Self-centring quiescent output voltage
- ★ Eight pin DIL package

## Applications

- ★ AF amplifier for radios
- ★ Intercoms
- ★ TV sound systems
- ★ Line drivers
- ★ Ultrasonic drivers
- ★ Small servo drivers
- ★ Voltage converters

## General Description

The LM386 is a general purpose power amplifier designed for use in low voltage applications. The voltage gain is internally set to 20 (26dB) to keep the number of external parts to a minimum. However, the addition of an external resistor and capacitor between pins 1 and 8 will allow the voltage gain to be increased to any value up to 200 (46dB). When operating from a 6V supply the quiescent power drain is only 36mW making the LM386 particularly useful for battery operation.

## Application Hints

To make the LM386 more versatile, two pins (1 and 8) are provided for gain control. If pin 1 and pin 8 are left open, as in Figure 1, the internal 1.35k $\Omega$  resistor sets the voltage gain to 20 (26dB). By connecting a capacitor from pin 1 to pin 8, as in Figure 2, bypassing the internal resistor,

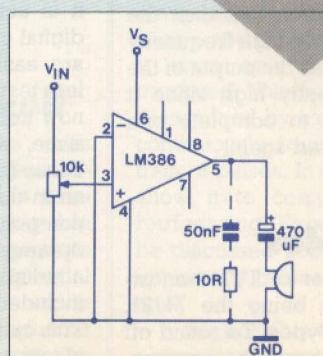
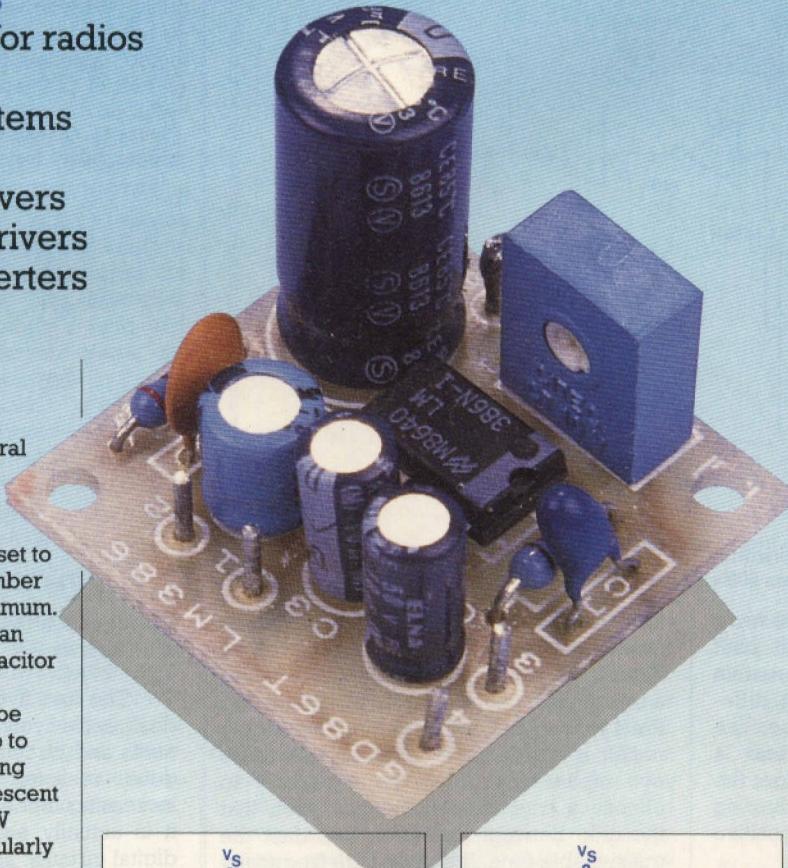


Figure 1. Amplifier with gain of 20 (26dB).

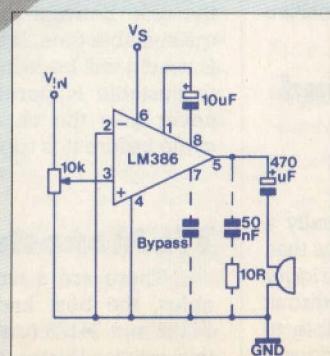
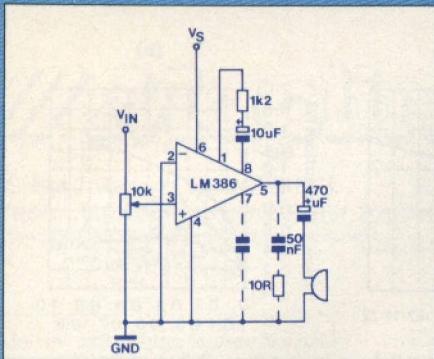


Figure 2. Amplifier with gain of 200 (46dB).

the voltage gain can be increased to 200 (46dB). The voltage gain may be set to any value between 20 and 200 by connecting a resistor in series with the capacitor, see Figure 3. Gain control may also be achieved by capacitively coupling a FET or resistor from pin 1 to ground. It is possible to connect external components in parallel with the internal feedback resistors to tailor the gain and frequency response for different applications; for example the bass response may be effectively increased by connecting a capacitor and resistor in series between pin 1 and pin 5, see Figure 4. A resistor value of 15k $\Omega$  will produce an effective bass boost of approximately 6dB. The lowest resistor value for stable operation is 10k $\Omega$  if pin 8 is open because the amplifier is only compensated for closed loop gains greater than 9; values as low as 2k $\Omega$  can be used if pin 1 and pin 8 have been bypassed.

## Power Supply Requirements

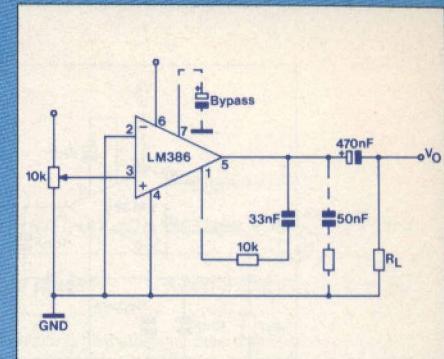
The LM386 will operate over a wide range of voltages between 4V and 12V making it ideal for battery operation, the optimum voltage for minimum distortion being around 6V. If the LM386 is used with a mains derived DC power supply it is important that the supply rail is adequately decoupled to



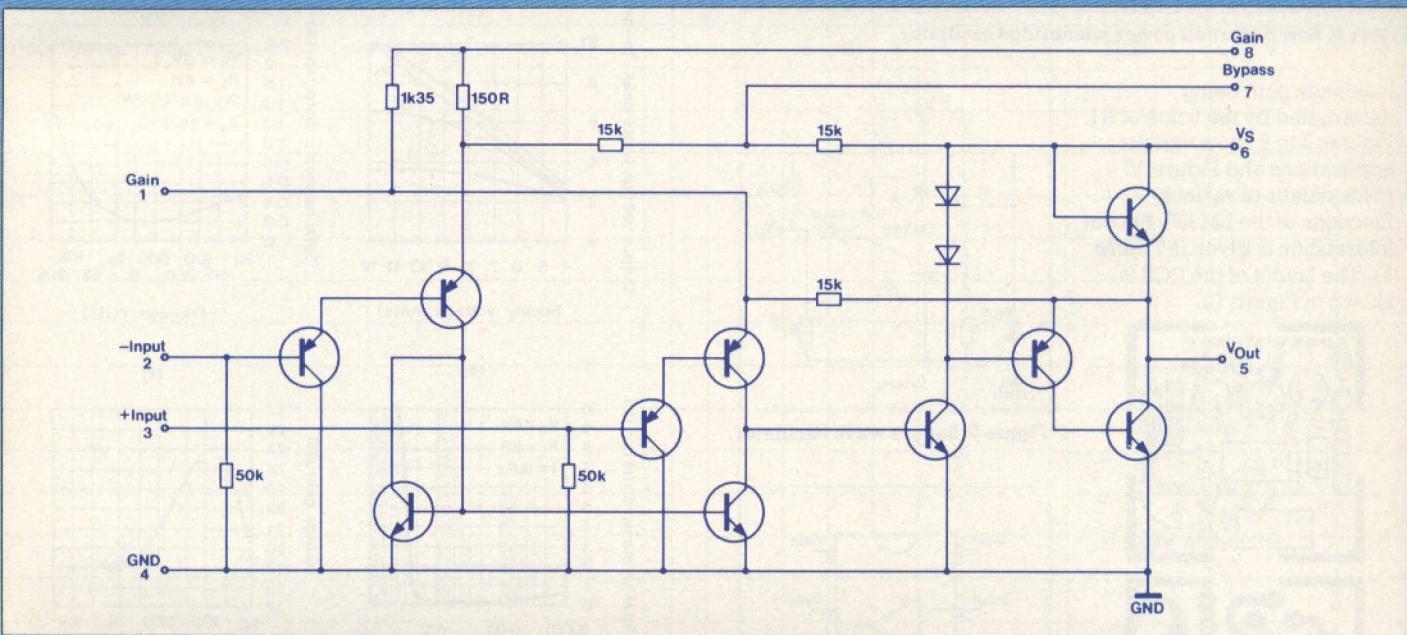
**Figure 3.** Amplifier with gain of 50 (34dB).



### An assembled PCB.



**Figure 4.** Amplifier with bass boost.



**Figure 5.** IC schematic diagram.

prevent the introduction of mains derived noise into the amplifier. Decoupling close to the IC is also necessary, to prevent any high frequency instability.

## **Input Biasing**

Referring to the IC schematic, Figure 5, it may be seen that both inputs are biased to ground with a  $50k\Omega$  resistor. The base current of the input transistors is around  $250nA$ , so the inputs are at approximately  $12.5mV$  when

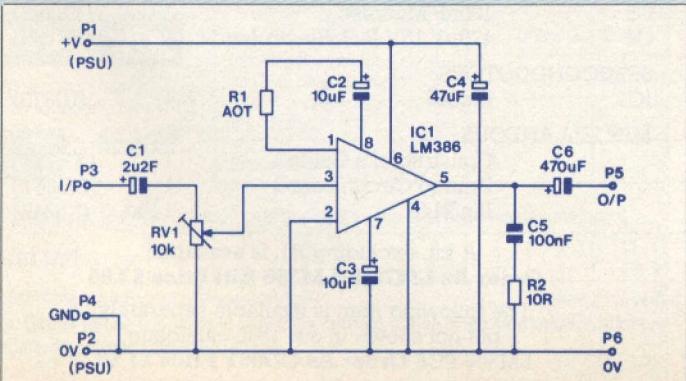
left open. If the DC source resistance driving the LM386 is higher than  $250\text{k}\Omega$  there will be very little additional DC offset. Where the DC source resistance is less than  $10\text{k}\Omega$ , the unused input can be shorted to ground to keep the offset low. For DC source resistances between these values any excess offset may be eliminated by connecting a resistor equal in value to the DC source resistance, between the unused input and ground. When using the

LM386 with higher gains it is necessary to bypass the unused input to prevent degradation of gain or any possible instability; this may be achieved by connecting a  $0.1\mu F$  capacitor or a short (depending on the DC source resistance on the driven input) from the unused input to ground.

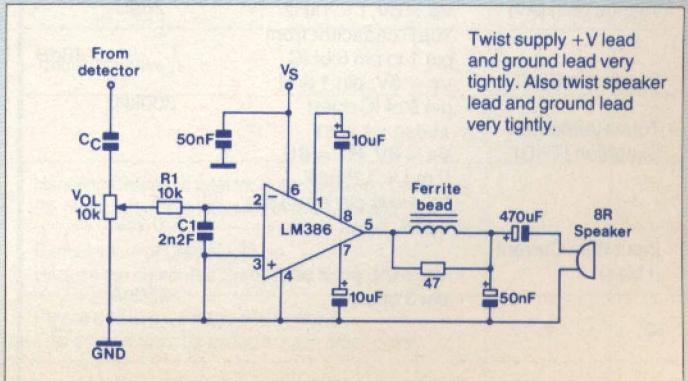
# **Printed Circuit Board**

#### A high quality fibreglass

PCB, with printed legend is available as an aid to construction of the basic LM386 amplifier circuit. Referring to Figure 6, the power supply is connected between P1 (+V) and P2 (0V), the optimum voltage being around 6V (see Table 1). Input signals are applied between P3 and P4 and the output is taken from P5 and P6 (the amplifier will operate satisfactorily into an 8Ω load). The overall voltage gain of the amplifier is set by RV1, the



**Figure 6.** Module circuit diagram.



**Figure 7.** Power amplifier for AM radio.

DATA  
FILE DATA  
FILE

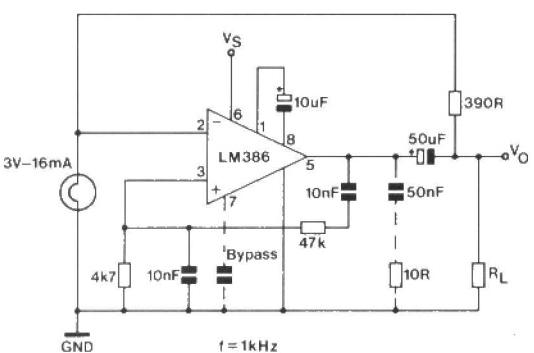


Figure 8. Low distortion power Wienbridge oscillator.

maximum gain being determined by the value of  $R_L$ . Figures 7 to 9 show various applications and Figure 10 gives details of various functions of the LM386. Pin out information is given in Figure 11. The layout of the PCB is shown in Figure 12.

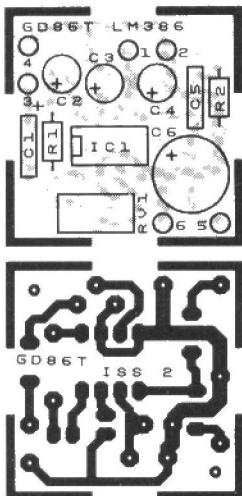


Figure 12. PCB overlay and track.

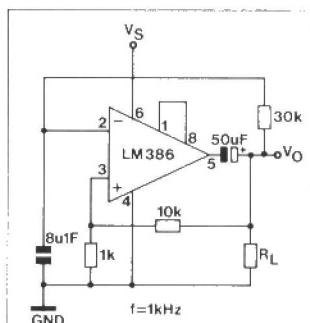


Figure 9. Square wave oscillator.

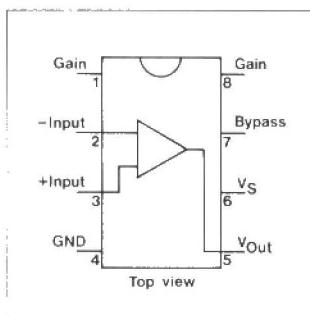


Figure 11. LM386 pinout.

Parameter	Conditions	Min.	Typ.	Max.
Supply voltage ( $V_S$ )		4V DC		12V DC
Quiescent current ( $I_Q$ )	$V_S = 6V$ , $V_{IN} = 0V$		4mA	8mA
Input resistance ( $R_{IN}$ )			50k $\Omega$	
Output power ( $P_{OUT}$ )	$V_S = 6V$ , $R_L = 8\Omega$ , THD = 10%	250mW	325mW	
Voltage gain ( $A_V$ )	$V_S = 6V$ , $f = 1kHz$	26dB		
	10 $\mu$ F capacitor from pin 1 to pin 8 of IC			
	$V_S = 6V$ , pin 1 and pin 8 of IC open		46dB	
Bandwidth (BW)			300kHz	
Total Harmonic Distortion (THD)	$V_S = 6V$ , $R_L = 8\Omega$ , $P_{OUT} = 125mW$ , $f = 1kHz$ pin 1 and pin 8 of IC open	0.2%		
Input Bias Current ( $I_{BIAS}$ )	$V_S = 6V$ , pin 2 and pin 3 open	250nA		

Table 1. Electrical characteristics of LM386.

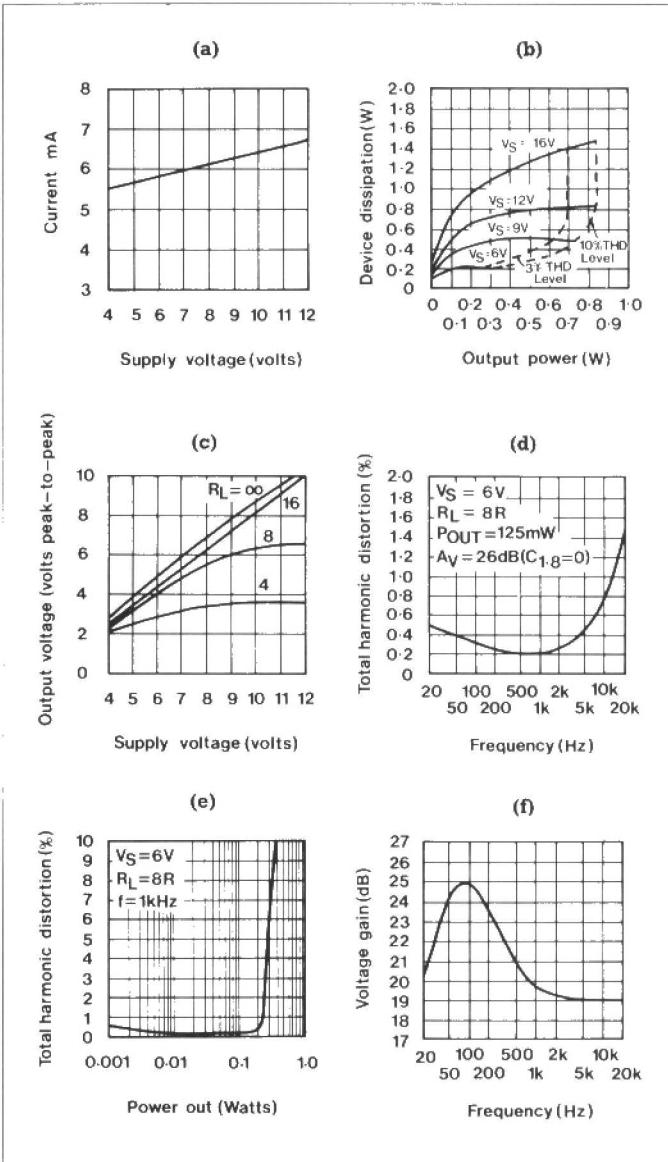


Figure 10 (a). Supply voltage vs quiescent current. (b). Device dissipation vs output ( $8\Omega$  load). (c). Peak to peak output voltage swing vs supply voltage. (d). Distortion vs frequency. (e). Distortion vs output power. (f). Frequency response with bass boost.

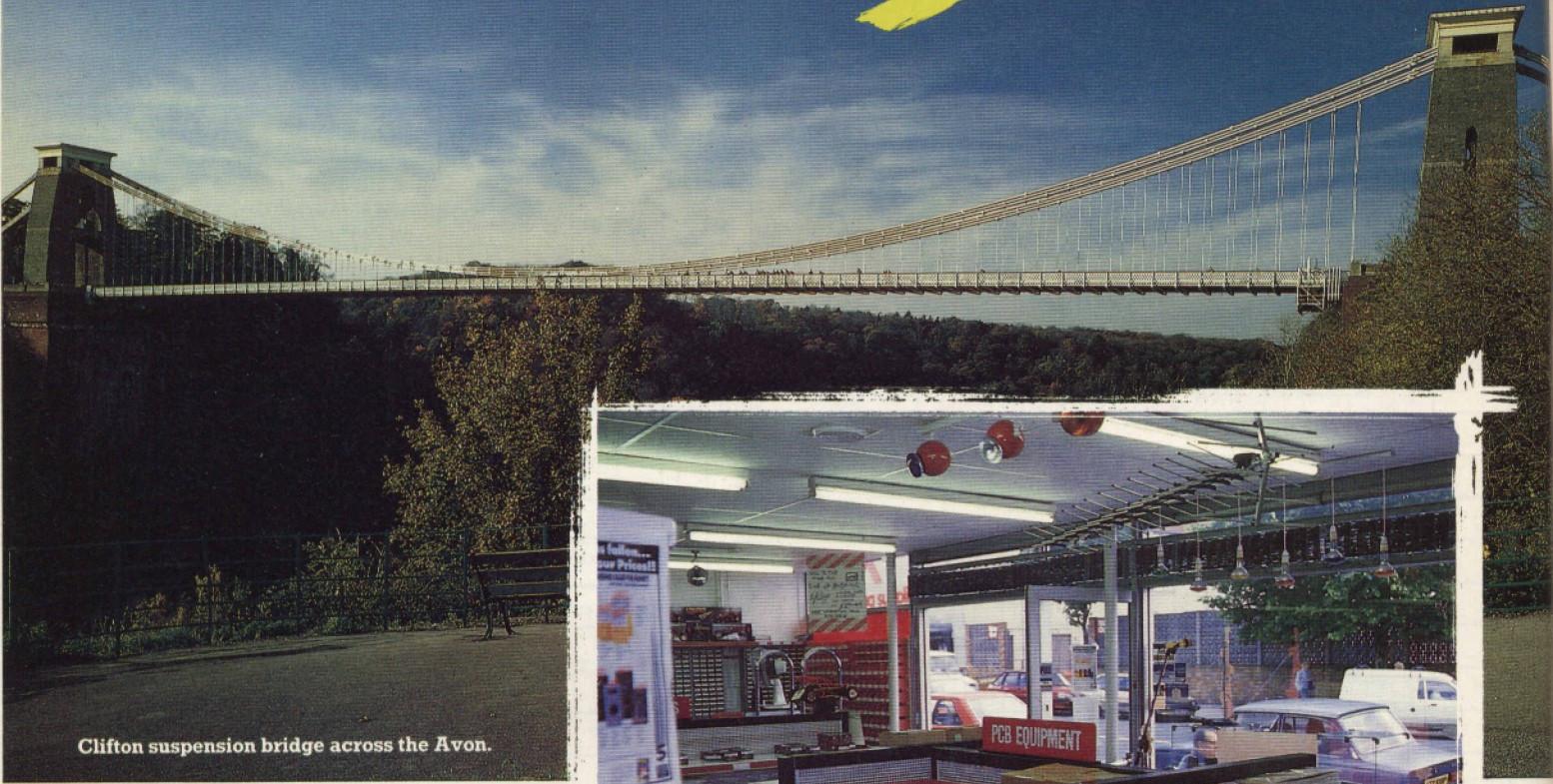
## LM386 BOARD PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	Select on test	1	
R2	10 $\Omega$	1	(M10R)
RV1	10k Vert Enclosed Preset	1	(UH16S)
CAPACITORS			
C1	2 $\mu$ F 35V Tantalum	1	(WW62S)
C2,3	10 $\mu$ F 50V P.C. Electrolytic	2	(FF04E)
C4	47 $\mu$ F 16V Minelect	1	(YY37S)
C5	100nF Minidisc	1	(YR75S)
C6	470 $\mu$ F 16V P.C. Electrolytic	1	(FF15R)
SEMICONDUCTORS			
IC1	LM386	1	(UJ37S)
MISCELLANEOUS			
Constructor's Guide		1	(XH79L)
Printed Circuit Board		1	(CD86T)
Pin 2145		1 Pkt	(FL24B)

A kit, excluding R1, is available:  
**Order As LM76H (LM386 Kit) Price £3.95**

The following item is available separately,  
but not shown in our 1989 catalogue:  
**LM386 PCB Order As GD86T Price £1.95**

# MAPLIN IN BRISTOL



Clifton suspension bridge across the Avon.

## Reported by Terry Johnson

Gateway to the South West. That's how the City of Bristol proudly boasts its presence to the World. Located at the junction of the rivers Avon and Frome, it has motorway connections to London, Birmingham, Exeter and Cardiff in Wales. Other primary routes take you to Devon, Cornwall, Somerset and all places south west. Similar connections are well provided by good services by British Rail.

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Granted County status in 1373, Bristol has a strong seafaring tradition going back to Roman times. Indeed, it was from Bristol that John Cabot, an Italian sailor set forth in 1497 to discover the new land of Canada. More recently it was in Bristol that Isambard Kingdom Brunel launched the now famous iron ship, the S.S. Great Britain.

Not too far away from the traditions of the sea, is the equally famous Clifton Suspension Bridge. Also constructed by I.K. Brunel in 1864, it is 702 feet long, and at its highest point is 275 feet above the low water level of the Avon. Moving nearer the city centre, you could visit the world famous Bristol Zoo, or the Giants Cave, a sight not to be missed! Bristol's great seafaring tradition is well illustrated



Inside the Maplin shop is designed for self-service and easy browsing.

in the Maritime Heritage Centre near to the S.S. Great Britain, and its industrial achievements in glass, potteries, tanneries and wine (Harveys - the 13th Century) are represented in the Industrial Museum. For the connoisseur, Harveys have their own Wine Museum.

Lovers of historic buildings are not forgotten, and in Bristol a wealth of excellent examples may be found. In particular, try to see the Red Lodge in Park Row which is furnished in both 16th and 18th Century styles, the Georgian House in Great George Street, and the Council House in College Green - now used as the headquarters for the city council. Also worthy of a visit is Royal York Crescent, the best known example of Regency architecture in Bristol, its massive 1,240 foot frontage took 33 years to complete.

Other famous landmarks and attractions include the Corn Exchange

building, Bristol Cathedral (founded in 1140), the Hippodrome, the Theatre Royal (the oldest working theatre in the country) and the Shakespere Tavern built in 1639.

But whatever you do in Bristol, whether it be sight-seeing or shopping, why not make a visit to the Maplin Shop, probably the finest electronic component store in the city of Bristol. Indeed, you should make Maplin your priority, as you will be assured of a friendly welcome, excellent service and be thoroughly satisfied with your visit.

Located amidst many other busy and bustling shops, its bright red front almost hypnotises one to enter and sample its many delights.

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Manager Keith Jenkins extends a warm welcome to all his customers.

you along Stokes Croft, Cheltenham Road and then into Gloucester Road. The shop is on your left, opposite the petrol station.

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Alternatively, for the privilege of paying around £4 you can take a taxi cab and get a guided tour of the city thrown in!

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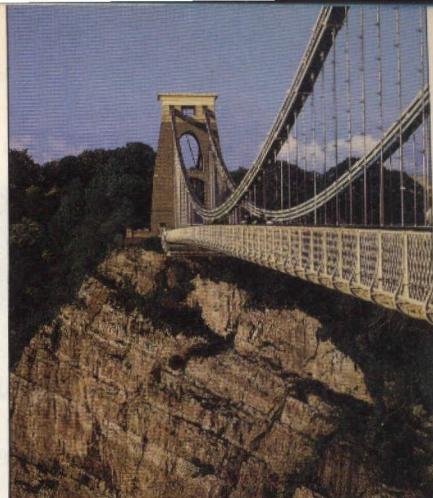
catalogue is laid out. The shop, being light and airy makes its self-service style shopping very easy - just pay at the check-out counter. Don't go without paying though, as all items are electronically alarmed! Having a computer controlled stock record, which is checked often, you are almost guaranteed that the item you require is in stock. If you are unlucky, then you need only wait two or three days for the part to arrive.

All items are full-spec branded devices; you won't find a 'junk box' here - perhaps proving even further that today's hobbyist is not just a 'dabbler' but becoming more professional in his approach to amateur electronics.

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Keith has his background firmly rooted in retail management and most definitely knows how to run a retail shop efficiently and smoothly. Adrian, on the other hand, has a truly professional background, having worked for Thorn-EMI before joining Maplin. He likes to keep right up to date with current advances in electronics and is probably more 'streetwise' than most. For advice on computers and related subject matter, speak to Jonathon - truly a computer 'buff'. Keith said, "We thoroughly train our staff and we expect them to know about electronics and to make a heavy commitment to learn about all aspects of the shop. The staff here are professional and dedicated."

Opened a year ago in November 1987, trade has been good and a firm base of regular customers has been built



Panoramic view across the bridge, showing the majestic cliff face below.

up. All this has been achieved despite local competition and with just occasional local advertising. Seems like word-of-mouth still counts!

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Bristol harbour view with cathedral backdrop.

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as featured in ETI October 1983. Mr. J. Luce, 56 Witney Road, Ducklington, Witney, Oxon. OX8 7TS

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**OLD AUTO TRANSFORMER** to run sodium/mercury discharge lamps. Please write to Adrian Gardiner, Hawthorn Lodge, Low Road, North Tuddenham, Dereham, Norfolk. NR20 3DH.

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**VIC 20 COMPUTER,** must have typewriter cartridge. Seon Smyth, "De Porres", 67 East Princes Street, Helensburgh. G84 7DG. Tel: 0436 71181.

**YAESU FRA7700** active antenna, FRT7700 antenna tuner. Tel: 0925 764985 or write G. Scott, 75 Wellfield Road, Culcheth, Warrington, Ches. WA3 4BT.

**WANTED, COPY PAPER** to test a REX Rotary 4080 photo-copier, or a supplier willing to supply small quantities. K. Twamley, 25 Davena Drive, Wesley Castle, Birmingham. B29 5UL.

**THANKS!** Mr. Alter, 18 Twyford House, Chisley Road, London N15 6PA, wishes to thank all those who wrote to him about the free Television magazines. All are now gone!

# FLORIDA HOLIDAY PRIZE DRAW WINNER!

Congratulations to Mrs Buxton from Stoke-on-Trent who has won the 'holiday of a lifetime' trip to Florida, USA which includes a visit to Walt Disney World's Magic Kingdom and Epcot Center, with several other superb attractions to visit in the nearby locality, including Sea World, Kennedy Space Center and, of course, the beautiful Florida beaches! She also receives £1000 spending money, to make her and her family's trip truly 'out-of-this-world'. Another 100 lucky prize winners receive tickets for a fabulous family fun-day out at Alton Towers, Britain's number 1 leisure park. They are as follows:

Mr. Burkey, Grays; Mr. Jackson, Wokingham; Mr. Holmes, Thirsk; Mr. Haynes, Aldershot; Mr. McCaughey, Lisburn; Mr. Breese, East Grinstead; Mr. Wharton, Chippington; Mr. Willets, Derby; Mr. Key, Birmingham; Mr. Morgan, Workington; Mr. MacNee, Spalding; Mr. Clarke, Birmingham; Mr. Smith, Peterborough; Mr. Wood, Huddersfield; Mr. Fairbrother, Ipswich; Mr. Wongor, Canvey Island; Mr. Bunney, Broughton-in-Furness; Mr. Williams, Birmingham; Mr. Goldsack, Sunderland; Mr. Fernandez, London; Mr. Fisher, Exeter; Mr. Tully, Ormskirk; Mr. Hinman, Lincoln; Mr. Moreton, Sittingbourne; Mr. Shillam, Sheffield; Mr. McAlpine, Craigaon; Mr. Williams, Pontyclun; Mr. Underhill, Crowborough; Mr. Cox, London; Mr. Matthews, Birmingham; Mr. Pearson, Skelmersdale; Mr. Storey, Hornchurch; Mr. Crisp, Worthing; Mr. Ford, Retford; Mr. Vickery, Torquay; Mr. Gayton, Liverpool; Mr. Aldridge, Kidderminster;

Mr. Pitcher, Llanelli; Mr. Flux, Gerrards Cross; Mr. Swanson, Gillingham; Mr. Gilbey, Oxford; Mr. Roberts, Liverpool; Mr. Wall, Worcester Park; Mr. Dicks, Stoke-sub-Hamdon; Mr. Humphries, Northwich; Mr. Oxley, Ilford; Mr. Toomey, Maidstone; Mr. Towill, Newquay; Mr. Randall, Bury St. Edmunds; Mr. Parsons, Braintree; Mr. Southern, Crowborough; Mr. Hall, Chatham; Dr. Williams, Norwich; Mr. Bird, High Wycombe; Mr. Drury, Hull; Mr. Dennison, Leicester; Mr. Palmer, Uxbridge; Mr. Cooke, Hull; Mr. Wilkins, Aldershot; Mr. Faiz, Croydon; Mr. Stewart, Whitley Bay; Mr. Brooks, Leeds; Mr. Hopkins, Manchester; Mr. Smith, Blackpool; Mr. Smith, Hartlepool; Mr. Kay, Seaham; Mr. Sturmy, Wolverhampton; Mr. Driscoll, Walsall; Mr. McCambridge, Banbridge; Mr. Thomson, Redcar; Mr. Turner, Cambridge; Mr. Adamson, Selby; Mr. Gilbert, Holyhead; Mr. Lochmueller, Northampton; Mr. Yeo, Exeter; Mr. Mantle, Tiverton; Mr. Green, Sandy; Mr. Newman, Leatherhead; Mr. Wooley, Crowborough; Mr. Vernal, Macclesfield; Mr. Woodhouse, Huddersfield; Mr. Sheriff, Barnsley; Mr. Turton, Leeds; Mr. McCarthy, Staines; Mr. Harding, Tewkesbury; Mr. Smith, Southampton; Mr. Armstrong, Loughborough; Mr. Barber, Lancing; Mr. Goodenough, Sherborne; Mrs. Kent, London; Mr. Lowry, Sunderland; Mr. Williams, Brierley Hill; Mrs. Munslow, Stoke-on-Trent; Mr. Irish, Welwyn Garden City; Mr. Stuart, Norwich; Mr. Weedon, Louth; Mr. Hyams, Blackburn; Mr. Clinch, London; Mr. Frater, Sunderland; Mr. Mohamed, Sunderland.

# 2mW Laser and Controller

Review by **Dave Goodman**

## Laser Tube and PSU

- ★ Helium-neon laser tube with 2mW output power
- ★ 1.8kV power supply with high ignition voltage
- ★ Protective aluminium case for tube and PSU
- ★ 240V AC operation

Introducing two thoroughbred projects from the stable of KTE, a company specialising in no-compromise kits of excellent design and performance. Each kit is complete – no optional boxes or miscellaneous items to buy – and contains only those parts capable of meeting stringent quality control requirements. A booklet is also supplied with each kit giving full constructional and operational details of the project.

Although the laser controller project has been primarily designed for use with the KTE laser system, it can equally be used with any similar laser having an exit port aperture of 0.5 to 0.75mm diameter.

The KTE Laser tube is available as a separate stock item under the code number XL11M. However, PCB's, boxes and components used in these projects are only available with the kit and are not supplied separately.

### Laser tube Specification:

Type:	Helium-Neon
Wavelength:	632.8nm (red light)
Typical power:	2.0mW
Ballast resistor:	68kΩ 4W
Starting voltage:	8kV
Operating voltage:	1.5kV
Operating current:	5mA
Tube voltage drop:	1.15kV ± 100V
Beam exit diameter:	0.75mm
Full angle divergence:	1.43mRadians
Overall dimensions:	260mm x 37mm Dia.

It is interesting to note that the laser tube is supplied in an aluminium sleeve

(‘full metal jacket’, perhaps?) with electrodes pre-wired and terminated in a 1/4 in. blade connector. The Anode (black lead) also has a 64kΩ 4W ballast resistor fitted.

### Power Supply Specification:

Type:	Laser PSU LPS 8000
Supply:	240V AC 50Hz mains
Power:	15 Watts
Ignition voltage:	8kV
Dimensions:	360 x 70 x 92mm

Both the Laser/PSU project and the controller project can be purchased ready-built and tested, for those of you that do not want the DIY version, the various versions, order codes, and prices are listed at the end of this article.

### Controller Specification:

Type:	Laser controller, LSG 7000
Image dimension:	0.35 x distance of projection
Mirror angle:	5 Degrees (x2)
Supply:	12V DC
Current:	0.25A (both motors at maximum)
Functions:	Automatic, manual, audio mono and stereo
Dimensions:	260 x 150 x 75mm

No power supply is contained in with this kit and I suggest a 12V @ 300mA AC adaptor is used, such as the Maplin XX09K.

## Laser Controller

- ★ Motorised mirrors for x and y light beam deflection
- ★ Three operating modes for Manual, Auto and Audio input
- ★ Lissajous and spiral graphics effects
- ★ 12V DC operation

## Laser and PSU

Before getting down to the actual construction of the kit, I recommend that you spend some time reading the instruction booklet supplied, especially the chapter concerned with safety. When you think about it, the project is designed to generate very high voltages which can arc over if misused, and there is also 240V mains directly on the circuit board! The laser itself emits a very high intensity light beam, which could possibly damage the retina when directed into the eye, so please keep these aspects in mind and make safety your priority.

So, down to business. The kit comes with components split into a series of polythene bags and the laser tube, see Photo 1, and case are neatly fitted into a moulded polystyrene block. What immediately impressed me was the tube. Instead of the expected glass envelope, with a few electrode pins projecting from



Photo 1. The laser tube.

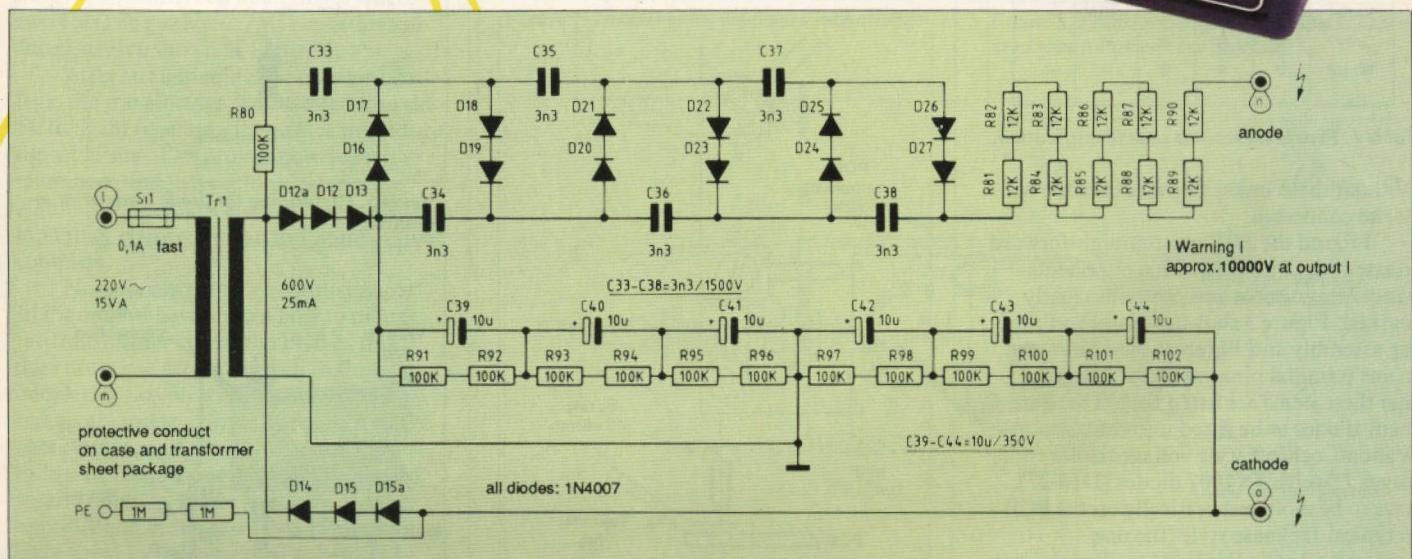


Figure 1. Circuit diagram of the laser PSU unit.

one end, we have the laser fitted into an aluminium housing with plastic end caps and pre-wired terminals. The anode wire exits the tube at the output port end, is black in colour and has a  $64\text{k}\Omega$  ballast resistor fitted, whereas the cathode wire is the white conductor, and both are terminated with insulated spade terminals.

Two clamps and spacer blocks are supplied for mounting the tube onto the PCB. I found a fair amount of pressure was required to insert the tube into these clamps and the fear was that either the tube or the clamps may be damaged during this operation, but no problems here as the clamps are reasonably flexible.

The printed circuit board is of excellent quality and made from glass fibre. Component positions are printed in yellow and the track layout has been printed in reverse on the top face of the PCB. This clearly shows the layout relationship between components and also gives the effect of being a double-sided circuit board, which of course, it is not.

A case is supplied for housing the electronics and laser tube and is made from 1.5mm aluminium, covered with a removable plastic film; all holes have been pre-drilled, so there is no immediate need

to search for the Black and Decker! At one end of the case, there is a 3.5mm diameter hole, from which the light beam exits; beneath this hole are three smaller holes that do not appear to serve any immediate function. In fact, this is the mounting position for the deflection motor bracket, which is included in the controller kit (More on this later).

Components supplied are all of high grade, European origin, and not a single sign of the Far East! The transformer, notated unconventionally as Tr1 on the legend and diagrams, is a PC mounting version and this explains why mains voltages are present on the PCB.

### Assembly Notes

Regular readers of 'Electronics' will notice a few deviations from the usual standard component designation on the circuit diagrams. Look at Figure 1 – S1 is a 20mm x 100mA fast-blow mains fuse, Tr1 is the mains transformer (and not a semiconductor) and termination points are identified by letters, not numbers. The mains voltage connection to the module is: LIVE to 'l', NEUTRAL to 'm' and EARTH to 'PE'.

I found the kit instructions easy

enough to follow, but thought that certain 'grey' areas could best be explained with the aid of explanatory drawings included here; a 'picture paints a thousand words' etc. Resistor identification can be a problem, especially if you are used to a particular colour code, or have no knowledge whatsoever. Some of the resistors in the kit have the standard four band markings and some have a five band marking – if in doubt, use an ohm-meter. Table 1 shows the five band resistor code, where the third band is always black.

One thing not explained in the text concerns an area of the PCB without any legend markings. This area, shown in Figure 2, is adjacent to the cathode terminal (Kathode) and has been added for future development. Having access to top secret future developments, and sneaking a look at various circuit diagrams, I am able to tell you that additional components could be added to allow the laser cathode to be modulated. This could be extremely useful for communication and measuring purposes and may well be a subject for future article or project developments. However, back to the present, I've shown how to link out this area of track in Figure 2 using three links made from scrap wire.

5 band code

Colour	1st ring	2nd ring	3rd ring (mult.)	4th ring	Tol.
Silver	-	-	-	x0.01	-
Gold	-	-	-	x0.1	$\pm 5\%$
Black	-	0	0	x1.0	-
Brown	1	1	1	x10	$\pm 1\%$
Red	2	2	2	x100	$\pm 2\%$
Orange	3	3	3	x1k	-
Yellow	4	4	4	x10k	-
Green	5	5	5	x100k	-
Blue	6	6	6	x1M	-
Violet	7	7	7	x10M	-
Grey	8	8	8	-	-
White	9	9	9	-	-

Table 1. Five band resistor code identification.

Without these links, the laser cathode will not be connected.

I found the PCB quite straightforward to assemble, Photo 2, with components easily recognisable and positions clearly marked. Figure 3 shows the laser terminal lug assembly and Figure 4 shows how the mains terminal pins are fitted. I suggest that these items are fitted first. There are many diodes to be fitted into the Walton/Cockcroft style voltage tripler stages. Twelve 1N4007 diodes (D16-27) have to be mounted vertically on the PCB in typical Japanese style (the one concession to the Far East!) as I've shown in Figure 5. Once the main components had been inserted, I soldered them in place and cut off the excess wire ends. Doing this left various sharply pointed ends

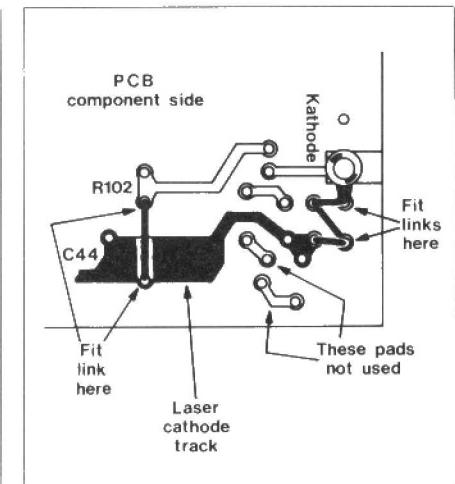


Figure 2. Future development modifications.

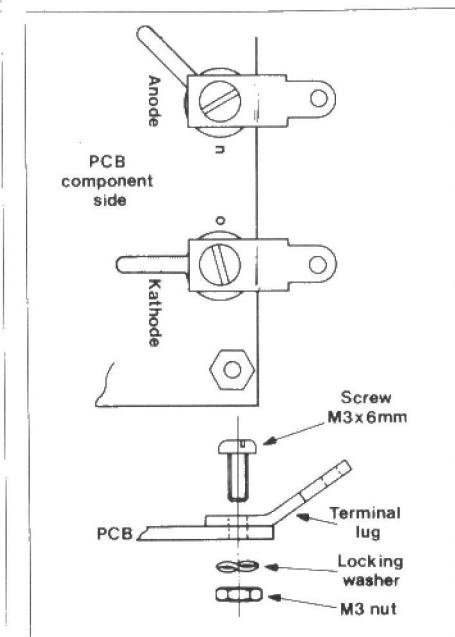


Figure 3. The laser terminal lug assembly.

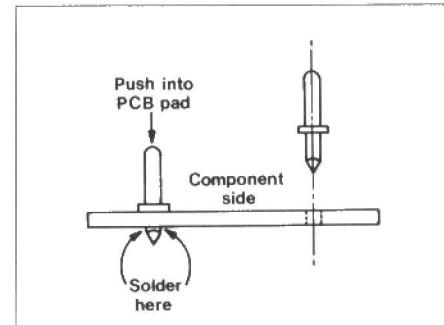


Figure 4. Fitting the mains terminals.

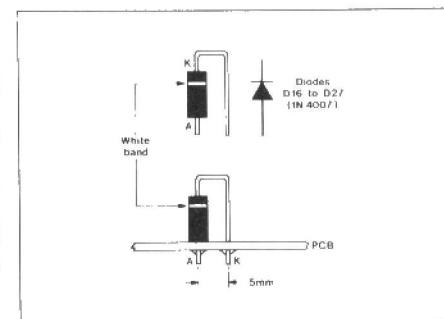


Figure 5. Preforming the diode leads prior to mounting.

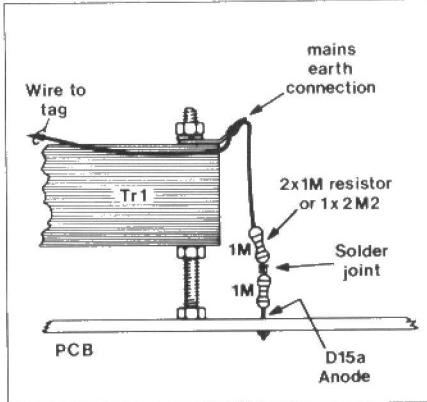


Figure 6. Fitting the two safety resistors.

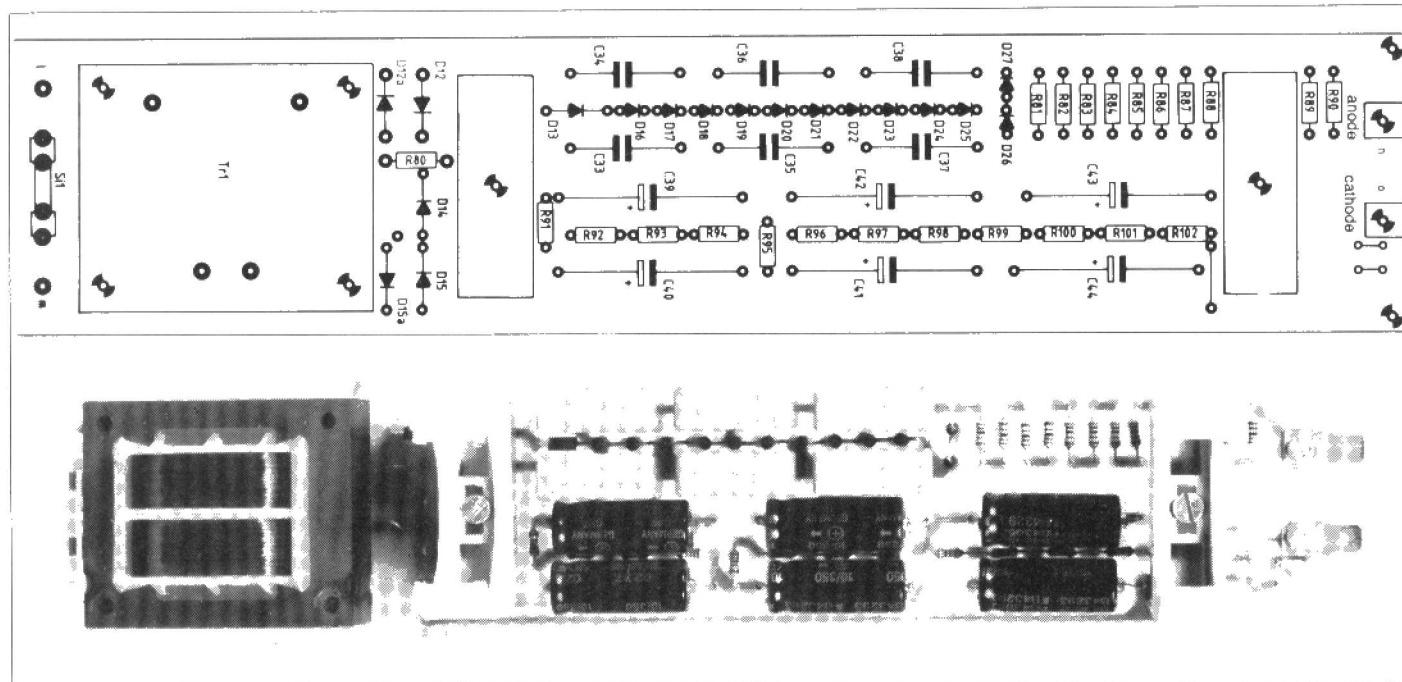


Photo 2. The laser PSU board layout.

sticking out at intervals around the board, not a very desirable situation where high voltage is concerned, so I thought it prudent to re-solder the board again ensuring all joints were nicely rounded and smooth. No sense in taking risks, especially as once fitted into the case, the module is difficult to remove again.

In the final paragraph of the booklet, recommendations are made for fitting 2 x  $1\text{M}\Omega$  resistors from the cathode to mains earth; this has the effect of lowering the potential between cathode and case (which must be earthed!) and reducing the possibility of breakdown between transformer windings. Reference is also made to additional diode modifications, but in fact, they are included already. Just at one side of diode D15a anode on the PCB, is an unmarked hole; this is where two  $1\text{M}\Omega$  or a single  $2.2\text{M}\Omega$  resistors are fitted, as I've shown in Figure 6.

After straightening the four terminal legs, the transformer was inserted into the PCB, again repeating the earlier procedure for soldering. The project now started to take shape and just required fitting the 20mm fuse and clips and the laser tube mounting clamps, shown in Figure 7, to be complete.

Now comes the more confusing part. In Figure 8, I have shown how to mount the transformer end of the PCB as this does not come across too well in the booklet. To begin with, four x 50mm screws are inserted into the case, from the outside first, and fixed with a nut and lock-nut. A third nut was then fitted and wound down to 10mm as shown. At the opposite end of the case, two 15mm screws were fitted in the same way as before. I found that if the 10mm height measurement is varied by more than 0.5mm, then the laser tube exit port does not align with the 3.5mm hole in the case end, and the beam deflects back into the case. KTE have even included a threaded bush for mounting the laser onto a camera tripod – thoughtful touch that – and a plastic cap covers both bush and lock nut on the inside, to prevent arc over.

I lowered the module over the 50mm screws until they just poked through on the component side and wound two nuts onto each of the four screws. This operation is a bit tricky and demands a degree of dexterity from the fingers. The nuts must now be wound down the screw thread to enable the module to be lowered

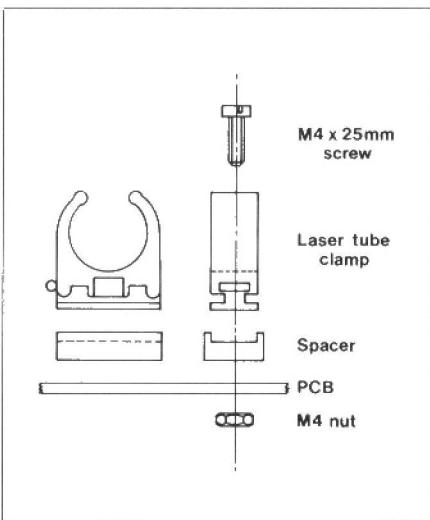


Figure 7. Details of the laser tube mounting.

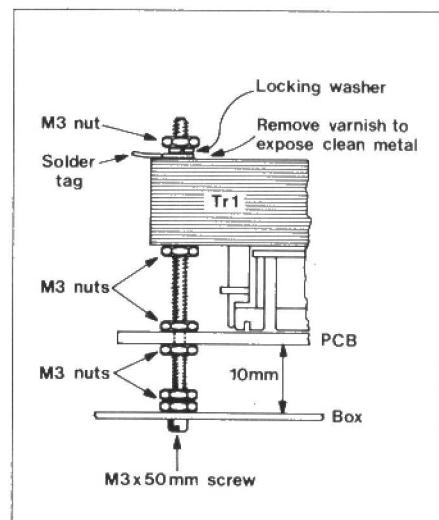


Figure 8. Transformer mounting details – these need to be followed very carefully.

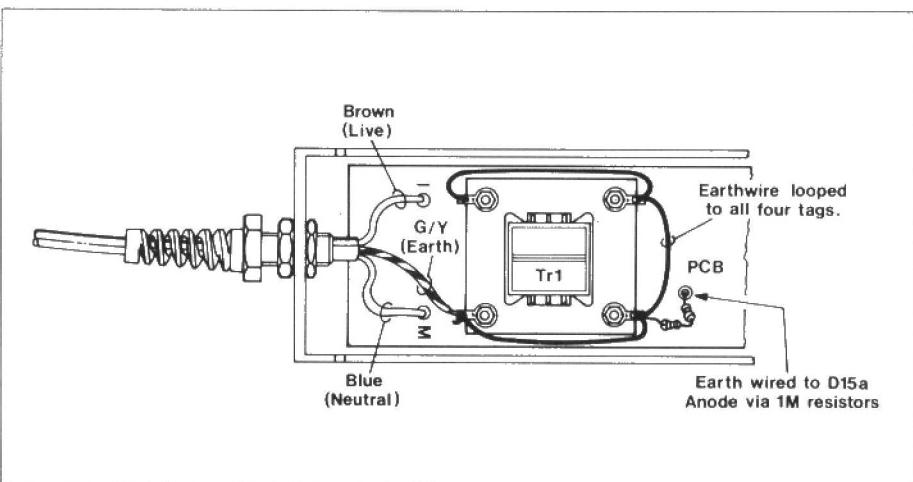


Figure 9. Connecting the earth wire and mains cable.

onto the 10mm spacer nuts. Perhaps this operation could be made easier by using plastic spacing bushes instead of nuts?

To make access to the transformer metalwork for earthing purposes, I had to scrape away the layer of varnish covering each of the four mounting holes. A solder tag fits onto each screw, followed by a lock washer and nut, and the complete assembly is gently tightened up. The finishing stages involve wiring all four tags together and fitting the mains cable, all of which are shown in Figure 9 and Photo 3. Don't forget to fit the front two PCB mounting nuts!

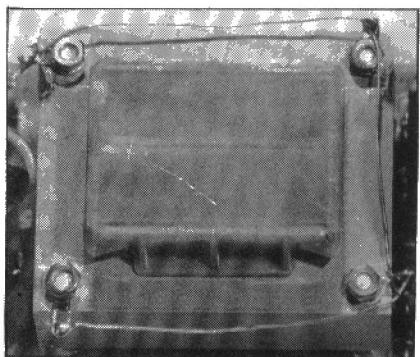


Photo 3. The essential earth protection loop.

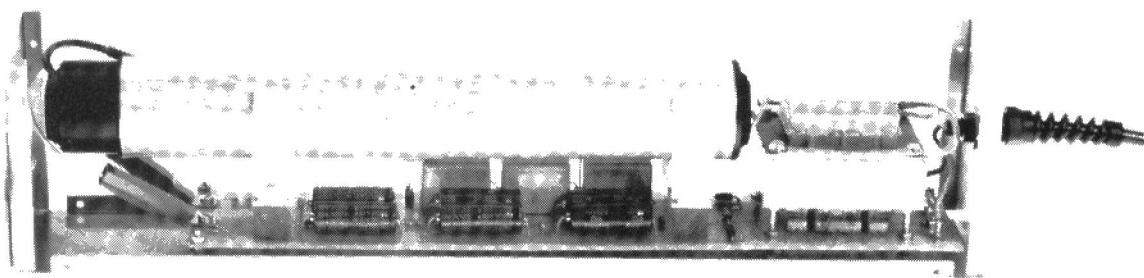


Photo 4. The completed laser.

As I mentioned earlier on, fitting the laser tube into the two clamps was a bit worrying at first, but you can be assured that it does fit. The black wire plugs onto the connector marked 'Anode' and the white connector onto the remaining 'Kathode' terminal. The clips click in place once they have been fitted and are quite hard to pull off again. A short length of insulating tape came in handy for holding these two high voltage wires onto the laser body thus preventing them from getting trapped in the case lid. A quick check of laser aperture alignment with the case exit hole proved worthwhile, as a slight re-adjustment was needed. Finally, the case lid was fitted and screws inserted. The extra three screws were fitted into the end panel holes and rubber feet stuck onto the base to complete the project, see Photo 4.

## Test of Nerves

Why is it that a 13A plug is never around when you need one, when at any other time there are usually several lurking in the tool box? Connecting any DIY kit to the mains is always a time of trial for both constructor and project, although any fears I had were quickly dispelled when the laser silently burst into life. A bright red spot of light, some 5mm in diameter, appeared on the wall opposite and placing my hand in the beam produced no sensation of warmth. The laser was left 'on soak' for the rest of the day – with the beam well out of eye view I might add – to see how it performed over a long period. The tube

does get warm, and so does the transformer which is to be expected, hence the case becomes warm after a while. No flash over, arcing or component breakdown problems were apparent and no odour of ozone, which often accompanies high voltage power supplies, were noticed.

## In Conclusion

The KTE laser and power supply kit is well presented, easy to build, of very good quality throughout and excellent value for money. The instructions supplied might have been a little more explicit for beginners to the hobby, but certainly adequate enough for the more seasoned constructor. Basic tools only are required for building this project and test gear is not necessary, which means that very few people from any age group would be likely to encounter problems with assembly. Having said that, I believe it important to understand that children should not be allowed near a working laser, unless under experienced supervision of course, and precautions are taken to avoid any direct eye contact with the beam. You also require a mains plug (not supplied) and to do something different with the laser (and who wouldn't?) you will need the controller project which I will review next.

## Laser Controller

The laser controller module circuit shown in Figure 10 is quite straightforward

to assemble, and except for four sockets, all components mount directly onto the PCB, Photo 5. Ten 200mm lengths of wire were required for connecting these sockets to the PCB and you will need a metre or so of spare hook-up wire to do this. The PCB legend becomes confused on some areas of the board where components have been tightly laid out and this is hardly surprising considering the quantity of parts that populate the board. Occasional reference to the overlay diagram helped when difficulties were encountered, and in similar fashion to the laser PCB, this board also has tracks printed on the top component side.

Once completed, the module fits into a moulded plastic box with a pre-printed front panel. Eight indicator LED's, fitted on the PCB, do not protrude through the front panel, but instead they are visible through translucent areas of the print mask – this makes a very neat finish.

Standard 3.5mm sockets, for the motor drive outputs and power supply input, are mounted on the rear panel along with a 5-pin DIN socket for audio input. Two 3.5mm plugs and a seven metre length of wire are also included for connecting up the deflection motors, but a 5-pin DIN plug, for making the audio connection, must be purchased separately. You will also need a power supply capable of delivering 12VDC at approximately 250mA. The total current requirement depends on the motor speed at any one time and varies accordingly up to a maximum of 0.25A with both motors

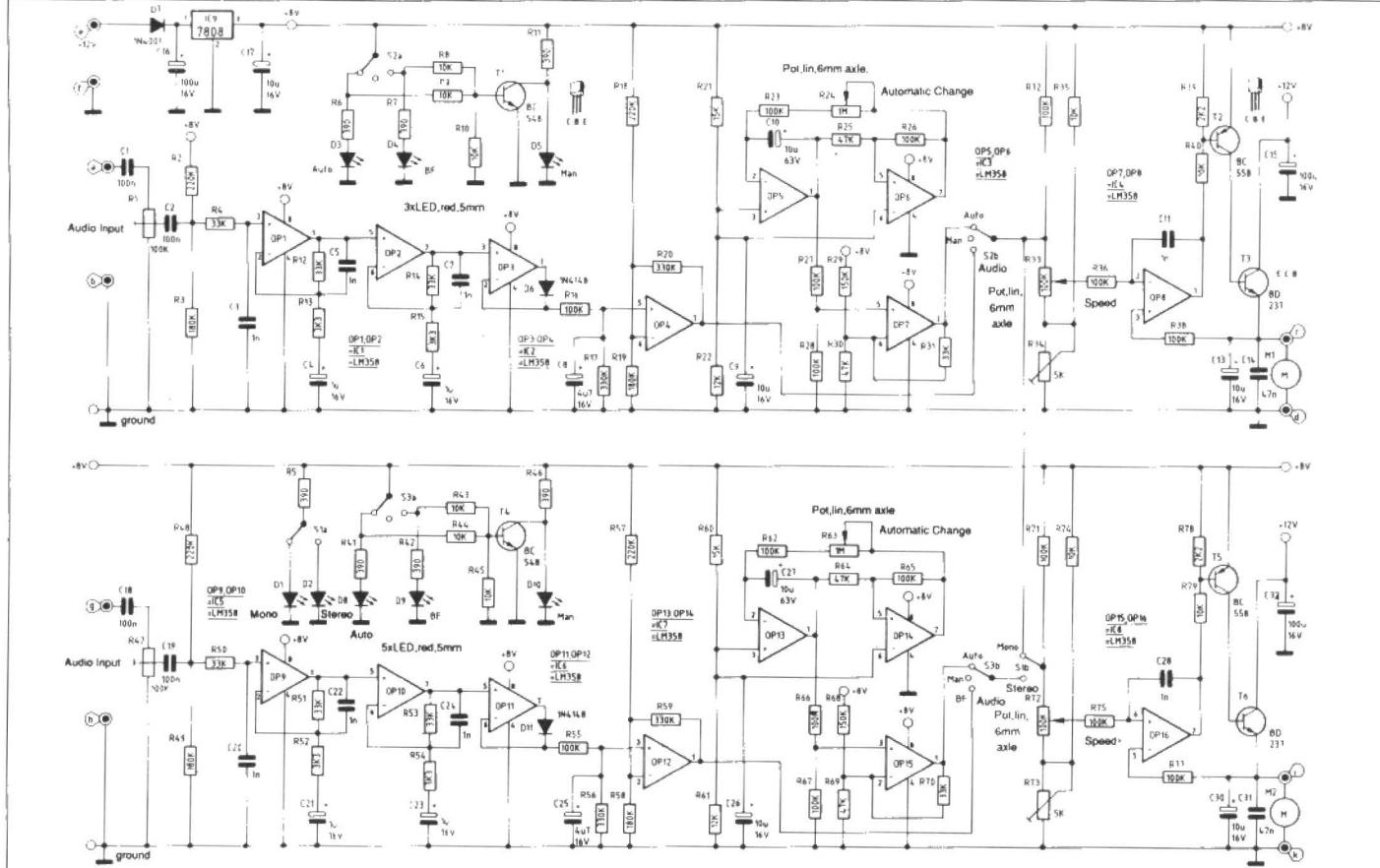
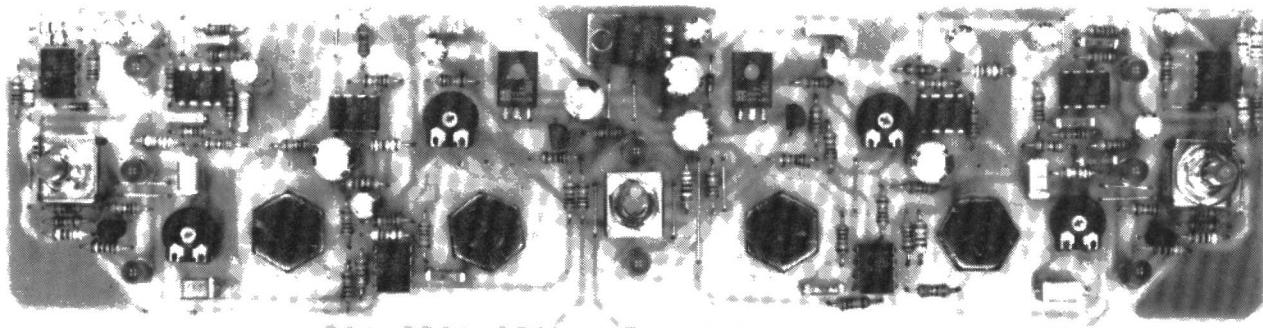
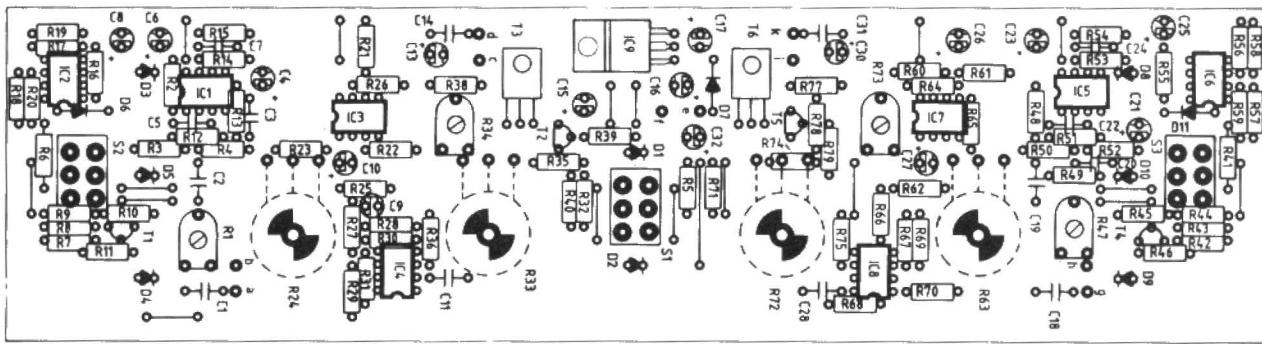


Figure 10. Circuit diagram for the controller.



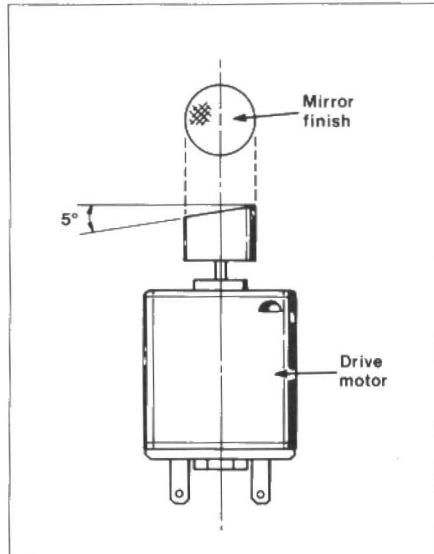
*Photo 5. Layout of the controller PCB.*

running at maximum. I can recommend the Maplin XX09K adaptor, which delivers 12.5V at 250mA, for this project – assuming you wish to use the 240VAC mains supply!

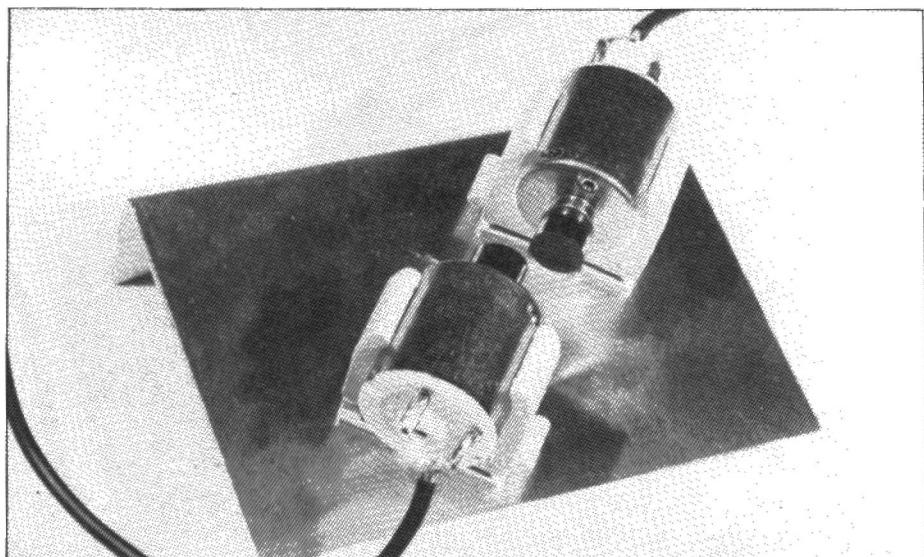
## *Operating Principle*

If a laser beam is directed onto a mirrored surface then a large percentage of the beam will be deflected, with some energy losses due to absorption. In this project, the mirror is made from a section of plated brass rod that has been mounted onto a small electric motor, see Figure 11 and Photo 6. You will notice that the top face has been machined down at an angle of five degrees from the perpendicular and given a highly polished finish. Two such

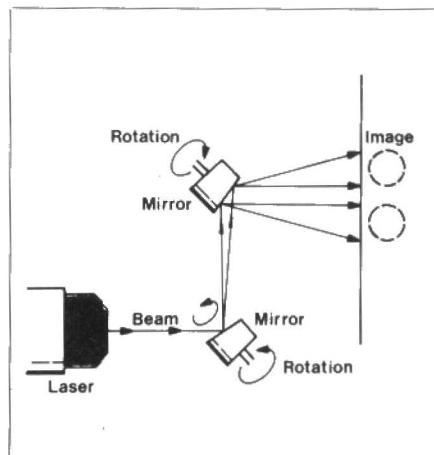
mirrors, known as motor deflection drive units, are mounted at 45 degrees to each other (and to the direction of the laser beam) so that the beam is deflected through 90 degrees by each mirror, as represented in Figure 12. A motor rotates the mirror and as the laser beam strikes its angled surface, a small circle of light is transcribed, which is then reflected onto the second mirror. If this second mirror were motionless, the image would be deflected through 90 degrees, thus projecting a circular image on the screen. However, if both mirrors are rotating, then the image is moved through 360 degrees, thus forming elliptical patterns of differing shapes and sizes according to the relating motor speeds.



**Figure 11.** Details of the 'motor deflection units'.



*Photo 6. The two motor drive units.*



**Figure 12.** Basic light beam deflection.

## Beam Bending

Three different methods of controlling the motors are available and these are MANUAL, AUTO and AUDIO. In MANUAL mode, the speed of each motor is determined by the appropriate channel RPM control (one for each motor channel) and both controls operate independently when either MONO or STEREO mode is selected. The maximum speed can be preset and the minimum speed is zero. Selecting AUTO mode allows the speed of each motor to be increased and decreased at a rate determined by the AUTOMATIC CHANGE control which varies the frequency of a triangular output waveform. In STEREO mode, RPM and AUTOMATIC CHANGE controls on each channel work independently; whereas MONO mode disables the channel 2 AUTOMATIC CHANGE control and both motors are then ramped up and down in unison from channel 1. Both channel RPM controls remain independent however!

The deflection motors can also be pulsed from a music signal, connected to the DIN socket input, when the AUDIO mode is selected. Either stereo or mono music sources can be used, provided that the minimum signal level is approximately 0.25 to 0.5V RMS. A sensitivity preset control at the input of each channel allows for large variations in signal voltages, up to 30VAC or so, therefore it is possible to use the speaker outputs from small disco's or domestic Hi-Fi units to modulate the laser. The effects produced in this mode are not actually 'sound to light' as the drive motors obviously cannot respond fast enough to music beats. Patterns produced tend to vary in shape and rotation direction, according to the music tempo and signal amplitude, and I found the best effects were made with both channel RPM controls set very close to minimum speed.

## PCB Assembly

There are a few points which I think are worth explaining in greater detail, as they may not be immediately obvious! For example, 18 links are required to be made and fitted in positions marked with a yellow line on the PCB – component lead cut-offs are useful for doing this. The two power transistors T3 and T6, and also regulator IC9, should lay flat after installation, see Figure 13 otherwise the front panel will not fit. For the same reason, LED's D1-5 and D8-10 are mounted such that the distance from PCB to LED base is 4mm, as shown in Figure 14. As with the laser PSU module, many of the resistors supplied in this kit are of the five band variety, so if in doubt refer to Table 1 or use a suitable meter. I initially found the mounting position for resistor R74 confusing, due to it being placed over two of the pads associated with potentiometer R72. The resistor does fit in accordance with the legend and terminals

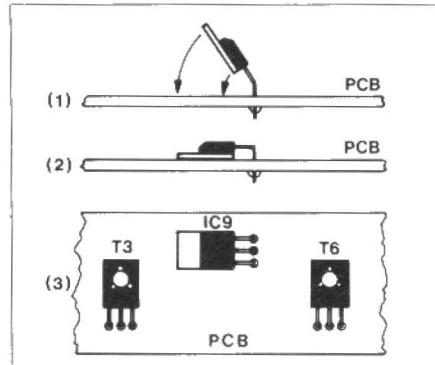


Figure 13. Mounting the two transistors and regulator.

from R72 solder on underneath (more on this later).

IC's 1-8 are dual op-amps, referred to as OP1-OP16 on the circuit diagram, and relate as follows:

IC No	Op Amp Nos
1	1-2
2	3-4
3	5-6
4	7-8
5	9-10
6	11-12
7	13-14
8	15-16

No sockets are supplied in the kit and the op-amps are soldered directly into the PCB which, being single sided, presents little problem if they have to be removed for any reason.

I found a few deviations from the parts list with both 10 $\mu$ F and 4.7 $\mu$ F capacitor voltage ratings. Some devices are of a higher voltage rating and therefore physically larger in size, but they still fitted the board – just! The + symbol for capacitor C9 is not clearly visible on either the PCB or overlay diagram and in case this is general with other boards, C9 positive lead fits into the position closest to R27.

Four potentiometers mount directly onto the PCB from the track side, as Figure 15 shows. The three potentiometer terminals do in fact solder directly to the board on this side, and the legend on the opposite face shows this in dotted print; you will need to bend the terminals at right angles first though.

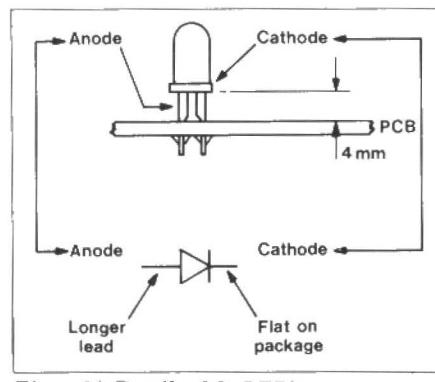


Figure 14. Details of the LED's.

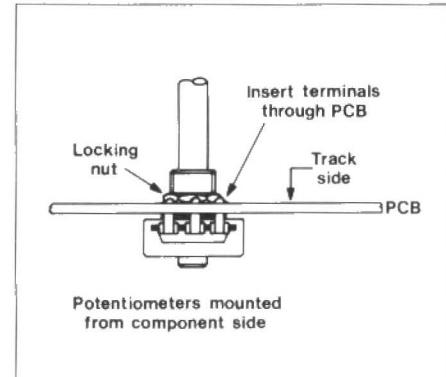


Figure 15. Mounting details of the potentiometers.

Mode switches S1-3 are mounted on the component side of the PCB Figure 16, in both end and centre positions. They also serve as fixing positions for the front panel and therefore, must be kept vertical during soldering.

The motor drive panel is simple to assemble and the bracket is screwed onto the laser PSU end panel, as can be seen from the various photo's and Figure 17. Final adjustments to angle the mirrors correctly were left for later on. The twin cable supplied was cut into two equal lengths and soldered onto the motor terminals and both 3.5mm plugs (the order is not important).

I had to drill four holes in the plastic case back panel to take four sockets: one 16mm for the DIN socket and three 6mm holes for the 3.5mm sockets. Each socket was then wired to the appropriately lettered position on the track side of the PCB. For plug and socket terminations, see Figure 18. I found it did not really matter which wire went to the socket terminal, but to clarify matters I suggest that you connect the wiring as follows:

1. 3.5mm Power socket.  
Sleeve to 'f' and Tip to 'e'.
2. 3.5mm motor No1 socket.  
Sleeve to 'd' and Tip to 'c'.
3. 3.5mm motor No2 socket.  
Sleeve to 'k' and Tip to 'i'.
4. DIN Audio socket.  
pin 2 to 'b' (common 0V)  
pin 3 to 'a'  
pin 5 to 'g'.

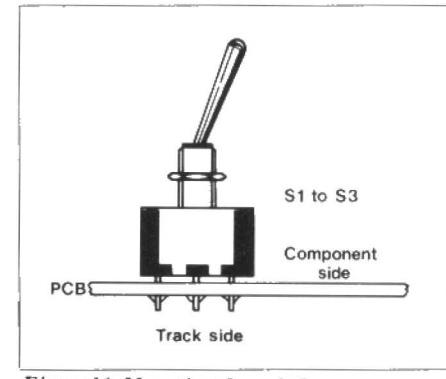


Figure 16. Mounting the switches.

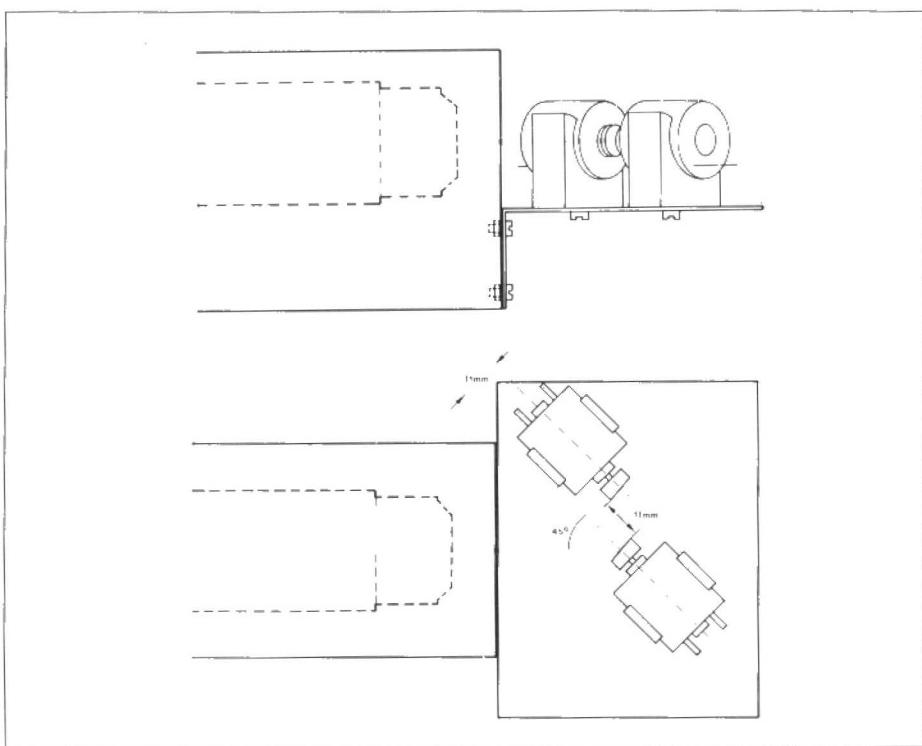


Figure 17. Mounting the motor drive panel on to the laser. Adjustments are critical.

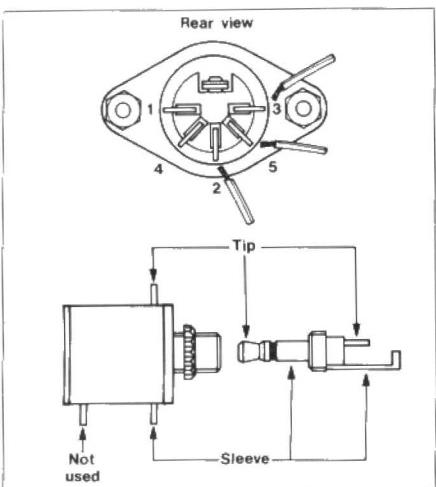


Figure 18. Terminations for the jack sockets.

By this time, the module was completed and ready for testing, see Photo 7. I left the front panel off at this time as adjustments were required to the four board mounted presets and this is not easy to do with the panel in place!

### Testing

Immediately after powering up the controller from a Maplin XX09K adaptor, the two motors ran at some speed. A few quick checks with a bench meter showed that under load, the regulator supplied 248mA at 12.52V DC. LED's appropriate to the switch position came on as each mode was selected and all was well. As the main instructions point out, preset R34 (for channel 1) and R73 are adjusted for minimum motor revolutions (or zero as

required) with the RPM controls set to minimum. This is done in the MANUAL position.

The laser was then powered up and the beam passed between the mirrors which necessitated further adjustments to the motor units. Figure 17 needs to be followed closely and I would remind you to keep your face well away from the mirrors. A fair amount of jiggery-pokery is required to set the mirrors and you may have to loosen the three bracket mounting screws along the way. I ran the first motor (nearest to the laser port) and positioned it so that the beam hit the mirror exactly at its centre; the second motor was then positioned until the reflected circular image (from the first mirror) fitted symmetrically into the second mirror. A sheet of white card placed approximately 30cm in front of the motor assembly showed a slightly elliptical, spinning circle which turned into a close resemblance of a daisy when the second motor was run, see Photo 8. A further adjustment was needed to prevent one corner of the image from clipping the edge of motor No1.

Presets R1 and R47 are set according to the available signal voltage as was mentioned earlier, but for a temporary measure, both preset wipers were set to half travel before finally boxing up the module and panels.

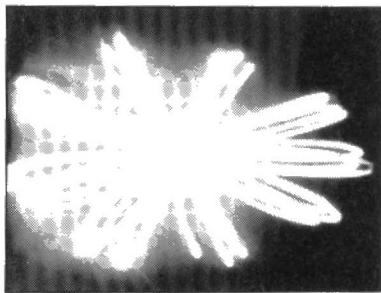


Photo 8. Pretty patterns!

### In Conclusion

The KTE laser controller kit is easy to build and set up and is of quite good quality for the price. The PCB legend could be clearer and the instructions could be a little more explanatory for the less experienced constructor. As with the laser PSU, only basic tools are required for building and testing the controller and experience in soldering techniques is obviously a must. This project does have the limitation of being an add-on for the laser project, but could easily be used to modulate other low power laser systems of similar style.

The following items are available from Maplin Electronics:

Laser & PSU Kit	LM72P	£99.95
Laser & PSU Ready Built	XM14Q	£179.95
Laser Controller Kit	LM73Q	£69.95
Laser Controller		
Ready Built	XM15R	£119.95
12V-300mA AC Adaptor	XX09K	£3.50
13A Nylon Plug	RW67X	£0.69
DIN Plug 5-pin A	HH27E	£0.25

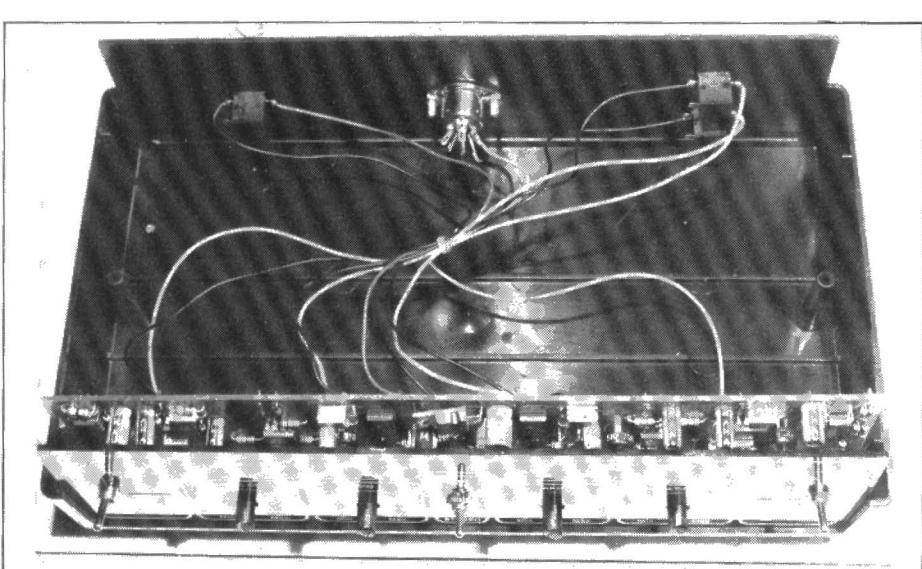
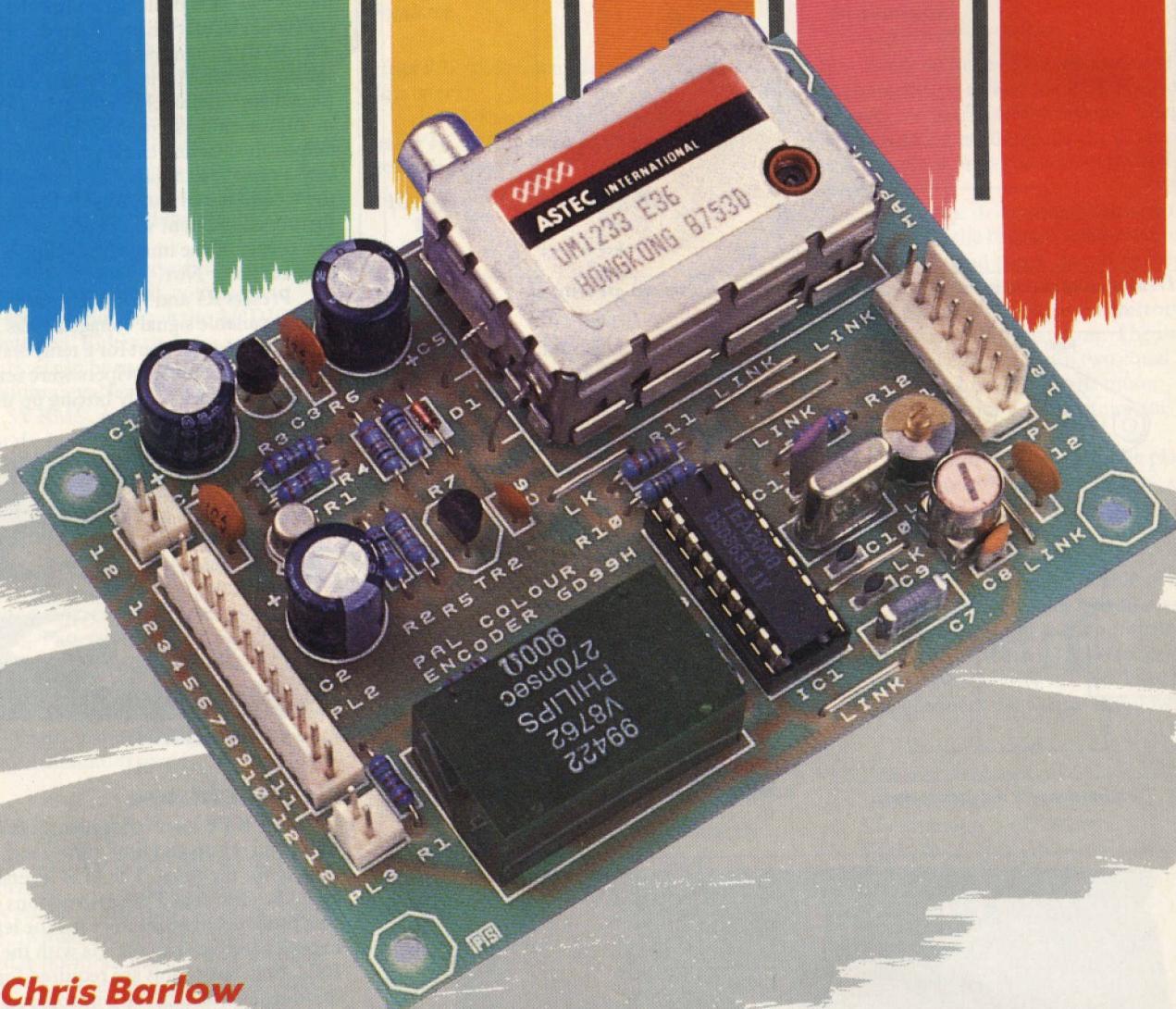


Photo 7. View inside the controller.

# TEA 2000 PAL

# COLOUR



by Chris Barlow

- Video and UHF TV Signal Outputs
- European PAL and American NTSC/M Standard Selectable
- 6 Bit Binary TTL Compatible Input Provides 64 Different Colours

- TTL Compatible Sync and Blanking Inputs
- Luminance Delay Line and Chrominance Filtering
- Crystal Controlled Oscillator
- On-board Voltage Regulator

# ENCODER

## General Description

The PAL colour encoder module is a building block used to convert digital signals into colour video, see Figure 1. The module provides two outputs, direct video for a monitor and modulated RF for domestic colour televisions.

At the heart of the unit is the TEA2000 which, until now, has only been presented with an application circuit in the Maplin catalogue. The project offered here is basically the same circuit but with the addition of a video buffer and a five volt regulator, see Figure 2. Table 1 gives all the electrical characteristics of the TEA2000.

## Application Hints

The digital circuits used to drive the encoder can be very diverse, from computer displays and arcade games to video pattern test generators. However, all these devices must provide the following TTL signals:

1. Composite sync (negative logic).
2. Composite blanking.
3. Red, green and blue (2 bits per primary colour).

The exact timing relationship of composite sync and blanking is quite involved. Therefore a good working knowledge of video techniques is essential and an excellent book on this subject is the Video Handbook (second edition) by Ru van Wezel. In addition to this Maplin have introduced a new IC, the SAA1043 Universal Sync Generator for PAL and NTSC standards.

The six bit binary colour data inputs are organised as two bits per primary colour and gamma correction is applied by the TEA2000 to the resultant luminance and chrominance levels. Each of the equally spaced intensity levels (for each primary colour) is combined with those of the other primary colours. This produces 64 output colours comprising a wide range of saturated and desaturated colours, black, white and two levels of grey.

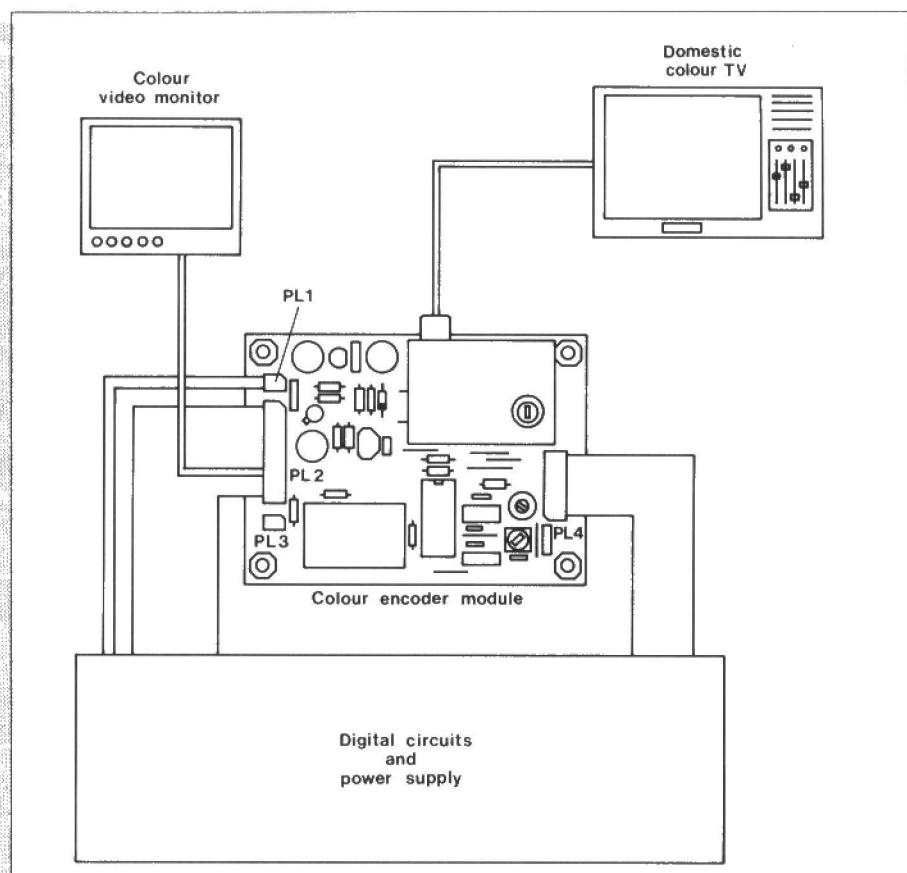


Figure 1. Digital to colour video.

COMPONENT	PAL	NTSC
XT1 CRYSTAL	8.667238MHz	■ 7.159100MHz
L1 DELAY LINE	DL270 (270nS)	■ DL330 (330nS)
L2 ADJUSTABLE COIL	15uH	■ 18uH
C8 PLATE CERAMIC	82pF	100pF
R10 METAL FILM 1%	510R	750R
R11 METAL FILM 1%	430R	510R
M01 MODULATOR	UM1233	■ UM1622
PAL/NTSC SELECT	HIGH (OPEN CIRCUIT)	LOW (PL4, PIN 5 TO 6)

■ COMPONENT NOT AVAILABLE FROM MAPLIN

Table 1. Electrical characteristics of the TEA2000.

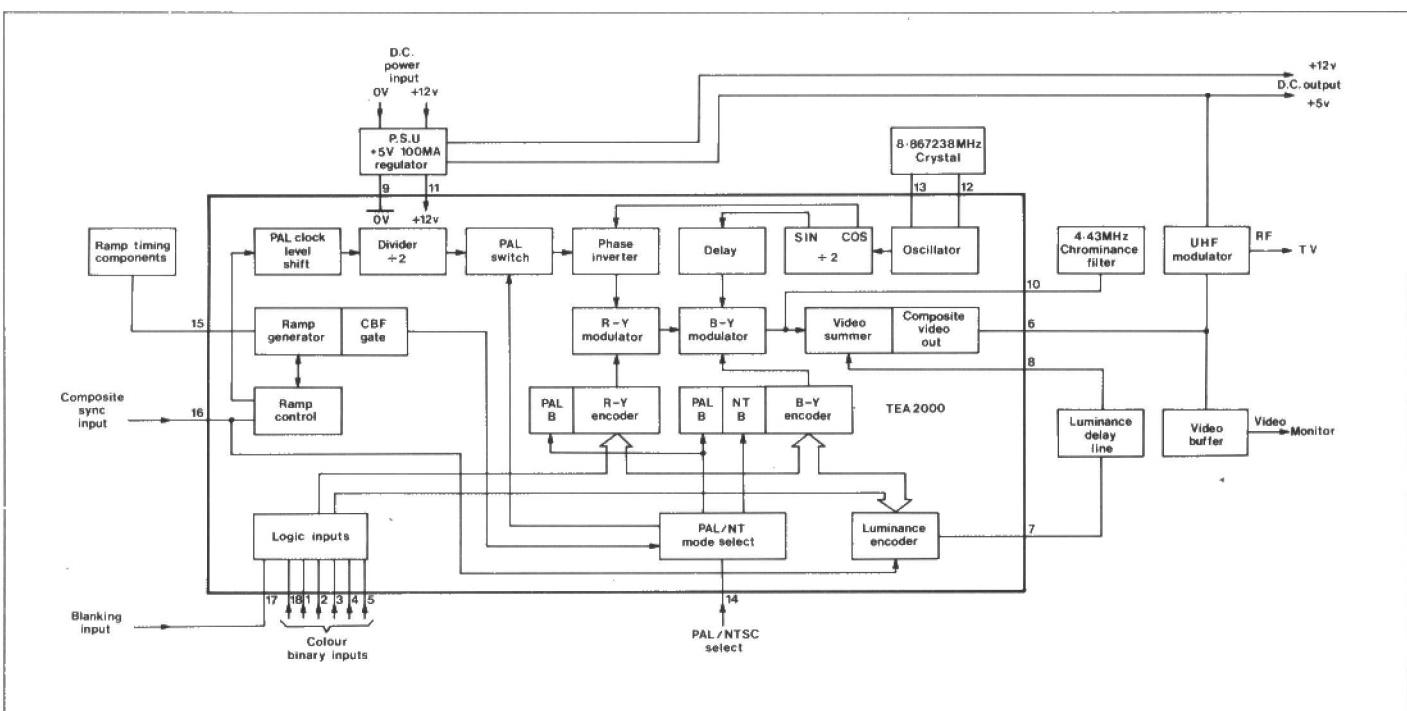


Figure 2. Block diagram.

## Circuit Description

In addition to the circuit shown in Figure 3, a block diagram is shown in Figure 2. This should assist you when following the circuit description or fault finding in the completed unit.

Any DC supply entering the circuit must have the correct polarity, otherwise damage may occur to the semiconductors and polarised components. The 12 volts for the circuit is applied to PL1 with the positive supply on pin 1 and the 0V ground to pin 2. The +12V supply rail feeds the video buffer and the TEA2000 colour encoder chip, with capacitor C1 providing the main decoupling and additional high frequency decoupling supplied by C3 and C12. This decoupled supply rail is then taken to pin 1 of PL2 and PL4 to provide a power output for any additional circuitry. The RF modulator MD1 requires a +5V supply which is generated using a small voltage regulator RG1, its output being decoupled by C4 and C5. This supply is also taken to PL2 and PL4, however the maximum current load on pin 2 must not exceed 90mA as overload damage may start to occur in RG1.

The TEA2000 (IC1) is a colour encoder and video summer which has an internal oscillator from which the R-Y and B-Y waveforms are generated. As can be seen from Figure 2, the chip has a complex internal structure which requires only a few additional components to make a finished working unit. The frequency of the internal oscillator is set using a crystal (XT1) and a trimmer capacitor (VC1) connected between

pins 12 and 13 of IC1. When using the PAL mode the frequency of the crystal must be set to 8.867238MHz or 7.15909MHz when in the NTSC mode. The output of the oscillator stage is divided to provide the four sub-carrier phases required in the encoder.

The combined luminance and sync signal appearing at pin 7 must be DC coupled to pin 8 via an appropriate luminance delay line. For the PAL mode the time delay is 270ns, but when in the NTSC mode a 330ns delay line must be used.

Chrominance filtering is accomplished by connecting a parallel tuned circuit (C8, L2) via a DC blocking capacitor C7 to pin 10 of IC1. The tuned filter must be set to 4.43MHz for PAL or 3.57MHz when in the NTSC mode.

The ramp timing components, C11 and R12, are connected to pin 15 of the TEA2000 which generates the necessary timing information for the colour burst and PAL phase switching. Alternative component values may be used to optimise the NTSC operation. Pin 14 of IC1 is used to select the PAL/NTSC mode and this pin is brought out to pin 5 of PL4. This input is TTL compatible and an internal pull-up resistor selects the PAL mode when this pin is not connected to 0V ground. A component list for PAL/NTSC operation is shown in Table 2.

Pin 16 of IC1 is connected to pin 4 of PL4 which is the composite sync input requiring a negative TTL logic signal, see Figure 4. For PAL operation the field sync must include line sync information.

Pin 17 of IC1 is connected to pin 3 of

PL4 which is the composite blanking input and must be high during sync and colour burst unless all the colour inputs are low at this time.

The colour inputs are as follows:

RED	R0 = IC1 pin 18 - PL2 pin 3
RED	R1 = IC1 pin 1 - PL2 pin 4
GREEN G0	= IC1 pin 2 - PL2 pin 5
GREEN G1	= IC1 pin 3 - PL2 pin 6
BLUE B0	= IC1 pin 4 - PL2 pin 7
BLUE B1	= IC1 pin 5 - PL2 pin 8

There are two binary bits per primary colour and these inputs are TTL compatible. A table showing 18 out of the 64 possible colours is given in Figure 5.

The composite video generated by the TEA2000 appears on pin 6 of the chip and is taken off to the TV modulator MD1 via R10 and R11. This signal is also capacitively coupled in to the input of the video buffer using a 10nF capacitor C6. The input impedance at the gate of the FET transistor TR2 is approximately 10MΩ, while the output impedance at the collector of TR1 is much lower, approximately 100Ω. The buffered video signal is then taken via C2 to pin 9 of PL2 and pin 1 of PL3. When using a video monitor with a high input impedance the termination resistor R1 must be placed in circuit by linking pins 1 and 2 of PL3.

## Printed Circuit Board

A high quality fibreglass PCB (stock code GD99H), with a printed legend to assist you in correctly positioning each component is shown in Figure 6. The following assembly hints should also prove

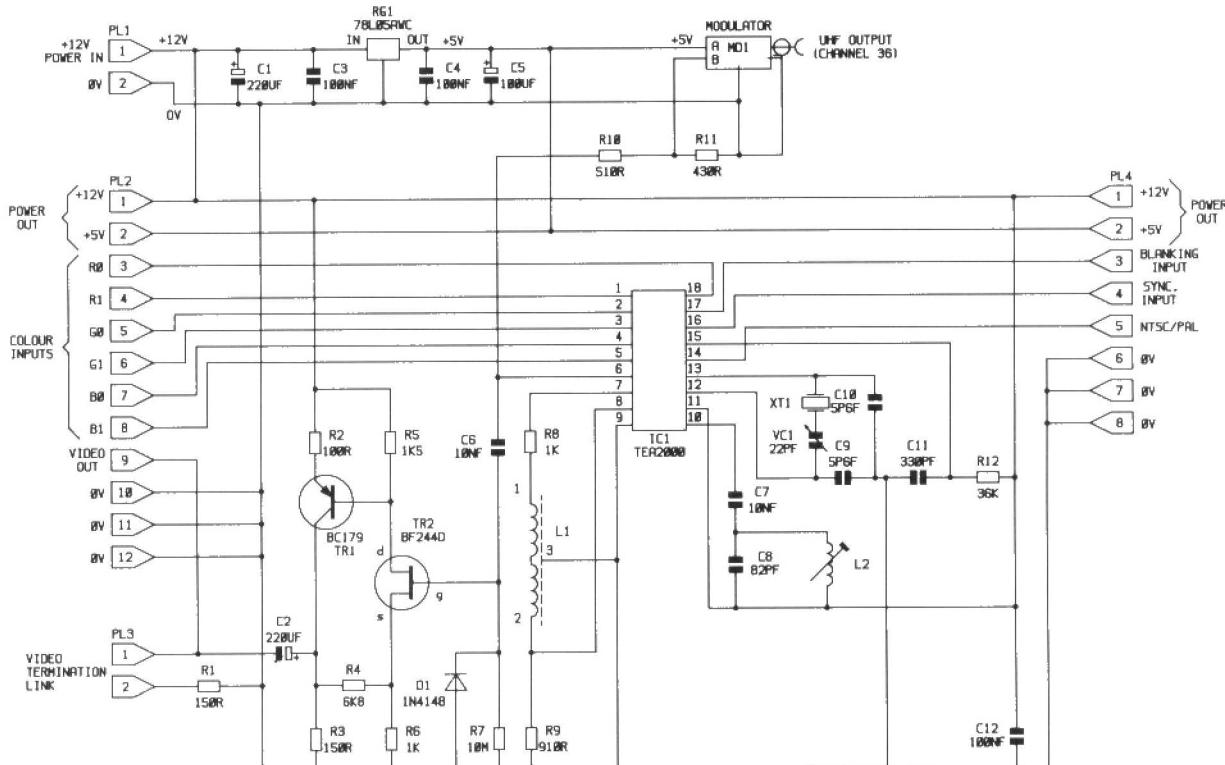


Figure 3. Circuit.

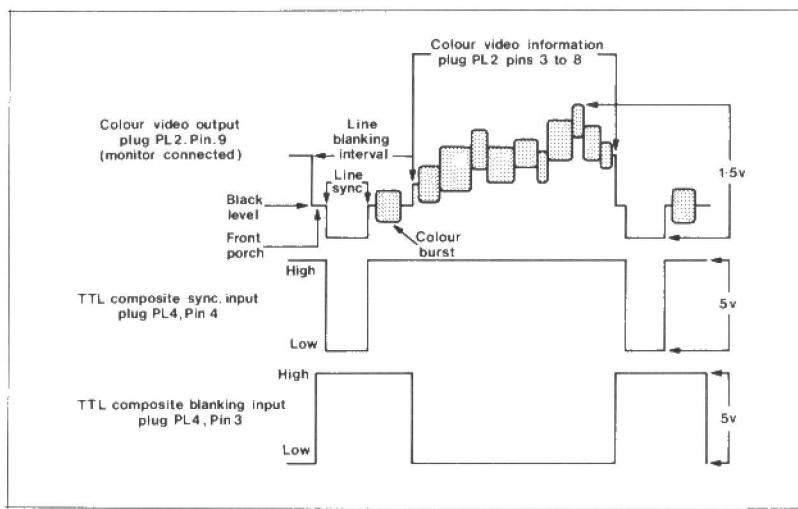


Figure 4. Video signal.

useful in making construction as straightforward as possible.

1. It is usually easier to start with the smaller components.
2. DO NOT forget to fit the wire links (LINK or LK).
3. When fitting the 'Minicon' connectors ensure that the locking tags are facing outwards to the edge of the PCB.
4. When fitting the semiconductors you must carefully match the case to the outline shown on the legend.
5. DO NOT over heat the crystal XT1.

## Testing and Alignment

Connect a 12 volt power supply to PL1, positive to pin 1 and negative to pin 2. Using a test meter in the positive line, measure the DC current which should be approximately 68mA. Remove your meter from the supply input and set it to read DC volts. Connect the meters negative lead to a convenient ground point (PL2 pin 12) and measure the positive 5 volts which should be present on pin 2 of PL2 and PL3.

Next connect the video output to a colour monitor, or the RF from the modulator to a colour television. Until the composite sync and blanking is applied to PL4 the monitor/TV screen should be blank, with the state of the colour inputs having no effect. With the correct sync and blanking the entire screen should change to the colour set by the bit pattern of the colour inputs, see Figure 5. If no colours are seen then try adjusting VC1 until the colour locks in, this will be when the crystal is oscillating at 8.867238MHz, see Figure 7. The chrominance filter L2 will have little effect at this time. However, its setting will determine the final picture quality of the digitally generated graphics.

The frequency output of the video modulator is factory set to channel 36 (591.5MHz). This should be suitable for most applications but if necessary it can be retuned by adjusting the ferrite core in its oscillator stage. All the adjustments should be made using a trimming tool, the one found most suited was the pot core type (stock code BR51F).

COLOUR	R0	R1	G0	G1	B0	B1
DARK RED	1	0	0	0	0	0
MEDIUM RED	0	1	0	0	0	0
LIGHT RED	1	1	0	0	0	0
DARK GREEN	0	0	1	0	0	0
MEDIUM GREEN	0	0	0	1	0	0
LIGHT GREEN	0	0	1	1	0	0
DARK BLUE	0	0	0	0	1	0
MEDIUM BLUE	0	0	0	0	0	1
LIGHT BLUE	0	0	0	0	1	1
BLACK	0	0	0	0	0	0
DARK GREY	1	0	1	0	1	0
LIGHT GREY	0	1	0	1	0	1
WHITE	1	1	1	1	1	1
ORANGE	0	1	1	0	0	0
YELLOW	1	1	0	1	1	0
PURPLE	0	1	0	0	1	0
PINK	0	1	1	0	1	0
CYAN	0	0	1	0	0	1

Figure 5. 18 of the 64 possible colours.

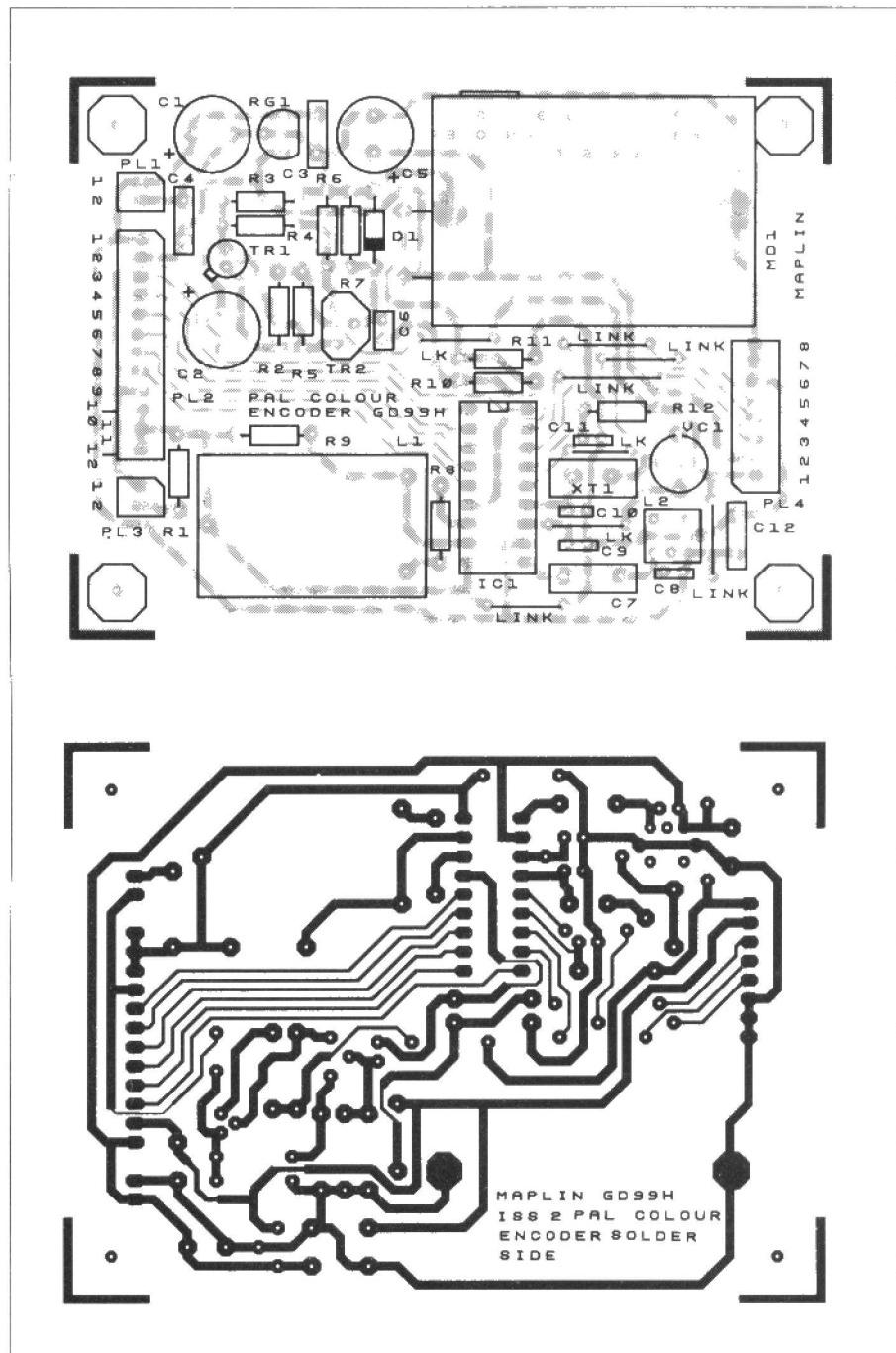


Figure 6. PCB layout and overlay.

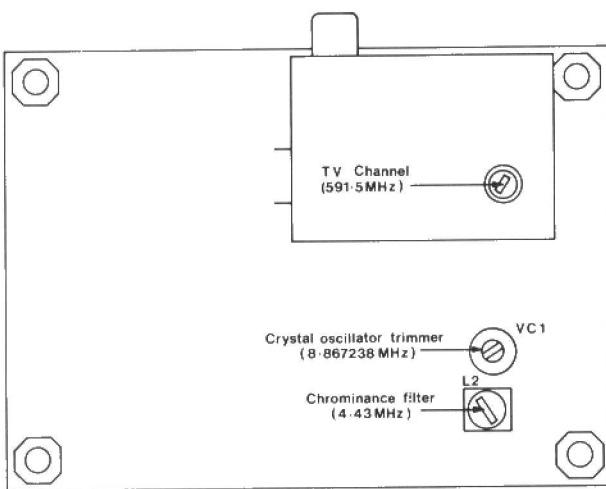


Figure 7. Encoder adjustment.

## Specification of Prototype Encoder Module

Power supply voltage:	+11.5V to +12.5V
Supply current at +12V:	68mA
Voltage regulator output:	+5V 90mA max
Video output:	1V p-p (75Ω load)
UHF TV output:	Channel 36 (591.5MHz)
TTL input voltage:	LOW +0.8V max HIGH +2.0V min
Crystal frequency:	8.867238MHz
Chrominance filter:	4.433619MHz
Luminance delay:	270ns

Parameter	Min	Typ	Max	Unit	Parameter	Min	Typ	Max	Unit
Supply Voltage pins 11/9	10.8	12	13.2	V	Sync tip level	-	5	-	V
Supply Current at 12V	-	55	-	mA	Output load resistor	0.47	1	-	kΩ
Oscillator Stability, pins 12/13 (Crystal type 4322 143 04051)					Variation of output amplitude	-	-	tbf	V(p-p)%
V <sub>p</sub> = 10.8 to 12V	-	+50	-	Hz	Tamb = 0 to +70°C	-	-	tbf	%
V <sub>p</sub> = 12 to 13.2V	-	-50	-	Hz	Over supply range	-	-	tbf	Ω
Digital Inputs					V on pins 11/9 = 10.8 to 13.2V	-	-	tbf	mV rms
CSYNC, CBLNK, PL/NT pins 16,17,14					Output Impedance (with 1kΩ load)	-	15	-	
R0, R1, G0, G1, B0, B1 pins 18, 2, 3, 4, 5					Residual Chrominance on white	-	30	-	
V <sub>in</sub> (low)	-0.5	-	0.8	V	Tolerance on luminance amplitude	-	10	-	V%
V <sub>in</sub> (high)	2	-	Supply	V	Tolerance on chrominance amplitude	-	10	-	V%
Input Capacitance	-	-	10	pF	Tolerance on chrominance phase	-	tbf	-	Q%
Input rise and fall times	-	-	200	ns	Chrominance band limiting, pin 10				
CSYNC, CBLNK, R0, R1, G0, G1, B0, B1 pins 16, 17, 18, 1, 2, 3, 4, 5					Internal resistance	-	1.5	-	kΩ
Input Current DC for V <sub>in</sub> = 0V	-	-	-100	μA	Luminance delay, pins 7/8				
Input Current DC for V <sub>in</sub> = 2V	-	-	20	μA	Nominal series resistor (±5%)	-	1.2	-	kΩ
PL/NT, pin 14					Nominal load resistor at luminance input (±5%)	-	1	-	kΩ
Input Current DC for V <sub>in</sub> = 0V	-	-	-500	μA	Ramp timing, pin 15				
Input Current DC for V <sub>in</sub> = 2V	-	-	-200	μA	With external RC circuit				
Composite Video Output, pin 6					R = 36kΩ; C = 330pF				
Output Amplitude (sync tip-white)	-	2	-	V	Start of burst from line sync	-	5.7	-	μs
					Burst width	-	2.5	-	μs
					Threshold for separation of equalising pulses and sync pulses	36	44	56	μs

Table 2. PAL/NTSC parts list.

## PAL COLOUR ENCODER PARTS LIST

### RESISTORS: All 0.6W 1% Metal Film

R1,3	150Ω	2	(M150R)
R2	100Ω	1	(M100R)
R4	6k8	1	(M6K8)
R5	1k5	1	(M1K5)
R6,8	1k	2	(M1K)
R7	10M	1	(M10M)
R9	910Ω	1	(M910R)
R10	510Ω	1	(M510R)
R11	430Ω	1	(M430R)
R12	36k	1	(M36K)

### CAPACITORS

C1,2,5	220μF 16V P.C. Electrolytic	3	(FF13P)
C3,4,12	100nF Minidisc	3	(YR75S)
C6	10nF Minidisc	1	(YR73Q)
C7	10nF Poly Layer	1	(WW29G)
C8	82pF Ceramic	1	(WX55K)
C9,10	5p6F Ceramic	2	(WX41U)
C11	330pF Ceramic	1	(WX62S)
VC1	22pF Trimmer	1	(WL70M)

### SEMICONDUCTORS

IC1	TEA2000	1	(UH66W)
RG1	μA78L5AWC	1	(QL26D)
TR1	BC179	1	(QB54J)
TR2	BF244D	1	(QF16S)
D1	IN4148	1	(QL80B)

### MISCELLANEOUS

L1	Delay line	1	(UH84F)
L2	15μH Adjustable Coil	1	(UH86T)
XT1	Crystal 8.867238MHz	1	(UH85G)
MD1	UHF Modulator UM1233	1	(FT30H)
PL1,3	Minicon Latch Plug 2-way	2	(RK65V)
PL2	Minicon Latch Plug 12-way	1	(YW14Q)
PL4	Minicon Latch Plug 8-way	1	(YW13P)
	DIL socket 18 pin	1	(HQ76H)
	Minicon Latch Housing 2-way	2	(HB59P)
	Minicon Latch Housing 12-way	1	(YW24B)
	Minicon Latch Housing 8-way	1	(YW23A)
	Minicon Terminal	3 Pks	(YW25C)
	P.C.B.	1	(GD99H)

### OPTIONAL

Trim Tool	1	(BR51F)
Video Lead 6	1	(FV90X)
Threader Spacer M3	1 Pk	(FG38R)
Isobolt M3 x 6mm	1 Pk	(BF51F)
Isoshake M3	1 Pk	(BF44X)
Isonut M3	1 Pk	(BF58N)

The parts listed above, excluding Optional, are available as a kit, but is not shown in our 1989 catalogue:

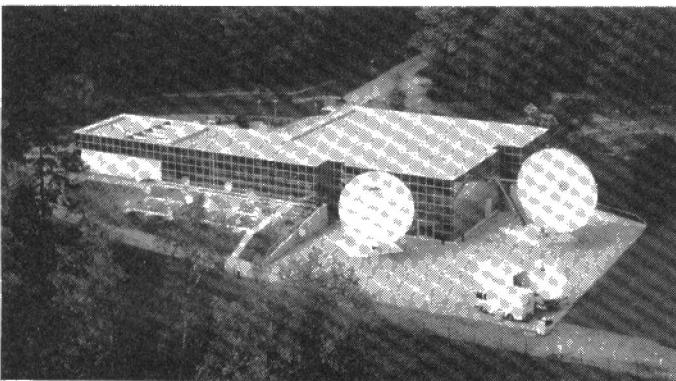
Order As LM66W (Pal Colour Encoder Kit) Price £19.95

The following item is also available separately:

PAL Colour Encoder PCB Order As GD99H Price £3.50

# NEWS REPORT

## Astra Satellite Launch Delayed



Astra's ground station in Luxembourg

The third stage motor on the Ariane rocket due to launch Astra on 1st November is causing problems and the launch has now been set back to mid-December. Astra expect to begin tests a few weeks after launch and still hope to be able to start commercial broadcasting early in February.

The satellite has 22 transponders of which 16 will be used, with the other six as back-ups. Six of the 16 channels have been sold so far, four to Rupert Murdoch's News International group and two to a Scandinavian company ScanSat. The latter have not yet supplied any information about what they plan to broadcast, but full details are available from Mr. Murdoch's plans.

One of his channels will transmit an upgraded version of the Sky Channel currently being broadcast on Eutelsat, one will broadcast a 24-hour news service, one will show international sport initially for 18 hours a day (though this will not be in English all the time), and the fourth channel will show a mixture of recent and old movies.

Initially, all the channels will be PAL encoded so you will be able to view them on an ordinary TV set. However, it is likely that the movie channel will be encrypted at a later date and this may mean that the channel will move to a MAC encoding system which can provide a more secure encryption than is possible with PAL.

Both satellites will be in a geostationary orbit, which means that they orbit the Earth at the same speed as the Earth turns and thus stay in exactly the same position relative to the Earth. The only place this is possible is directly over the equator and this is where the satellites will be. Astra will be at 19.2°E and BSB will be at 31°W.

It seems likely that BSB's squalar will be too small to pick up the Astra signals reliably which is a shame because whereas a dish aerial must point directly at the satellite required, a flat aerial is less directional, its 'gain' being proportional to its apparent surface area as seen from each satellite, and could therefore be fixed and still receive both the satellites. A flat aerial sited to point directly between Astra and BSB would provide 87% of its maximum 'gain' to both satellites.

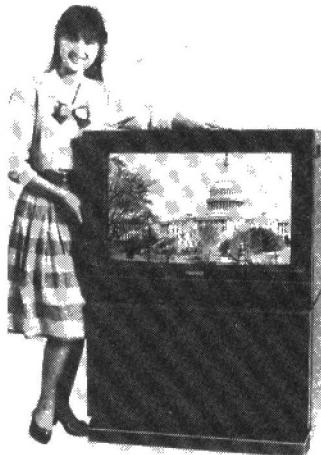
## Organic Transistor

The first practical transistor using an organic compound has been developed at Cambridge University. Chemical techniques developed there make it possible to use as the active layer in transistors or diodes, the polymer, polyacetylene. Although devices made with this material perform in the same way as conventional components, the nature of the physics is totally different. Essentially, electrons in conventional materials can exist in only one of two bands, where they are effectively 'tied' to the atoms in each band. In the new material devices, the polymer is a chain of carbon atoms linked by different bonds. Electrons associated with these bonds can be in both conduction bands, thus making a semiconductor with a band gap of 1.5 volts.

## MAC Is On Its Way

BSB is committed to broadcasting in D-MAC and most of the rest of Europe in D2-MAC when the later Eutelsat satellites are launched. Rupert Murdoch's channels will be in straightforward PAL, but even they may change in time. All the approved Astra decoders will have sockets so that a MAC decoder can be simply plugged in later. The advantage of MAC is that it completely separates the luminance and chrominance signals so that the picture can contain a higher definition.

Later MAC will allow true high definition TV to be developed where the broadcaster can double the number of lines in the picture, 625 up to 1250, double the frame rate, from 25 to 50, and change to a wide screen format, the present aspect ratio of 4:3 will become 16:9 (the picture shows Toshiba's wide screen HDTV set).



Of course to enjoy the benefits of MAC we will all have to change our TV sets, just putting a decoder in front of a PAL set will not improve the picture (although it would if your set has RGBY inputs - pretty unlikely, but a few sets have - and the decoder has RGBY outputs). The direct change to MAC is not dramatically different, but the change to true HDTV is. The picture takes on the quality of a slide projector with sharp, deep clear colours and tremendous detail.

But all that is a few years in the future, although some Japanese companies are already producing video cameras and recorders that can cope with true HDTV. For the moment Mr. Murdoch has taken the only sensible course to broadcast in PAL since the MAC decoder chips will not be in production in time for the start of his new channels.

## Superfast Photodiode Reported

A special photodiode detector has been developed with a bandwidth of over 110GHz at a wavelength of 830nm. The diode which has a quasi-Schottky contact is believed to be the fastest device yet reported. It has been made based on a semi-transparent platinum Schottky barrier photodiode, (Hirst Research Centre).

## New Optical Cable

The world's longest unboosted optical cable was laid early in May of this year by British Telecom between Holyhead and Portmarnock in the Irish Republic. The 80 mile link just recently opened is intended to carry speech, data, text, graphics and facsimile at 140Mbaud.

## Maplin's New Shops

A variety of complications have delayed the opening of Maplin's new shops, but the latest situation is that they should all be open by early 1989. The first to open will be the Nottingham shop, located on the north-east corner of the city's ring-road. Car parking is quite good outside or in adjoining streets or there is a public car park just across the road. The shop at 86-88 Lower Parliament St. (tel: 0602 410242) is just a few minutes walk from the city centre, and about 10 minutes drive from junction 25 (to the south) or junction 26 (to the north) from the M1. The shop is about 1 mile north of the main railway station.

The delay at Leeds has been caused because a slightly better position for the new shop has recently become available. Instead of being tucked out of sight in Byron Street, We'll now be sharing part of the newly opened Carpet World building right on Regent Street. The added advantage here is that the building has its own car park for customers. Centrally located a few minutes walk from the city centre, it is very easy to reach from the end of the M1, M621 just 1½ miles to the south. This shop too is about one mile north of the city's main railway station. Tel: 0532 449200.

Legal difficulties have delayed our new London store, but we are hopeful that everything will be resolved within the next few days, and that we shall be open before the end of 1988. This new store is in Burnt Oak on the Edgware Road A5 and just around the corner from Burnt Oak underground station on the Northern Line. Tel: 01 951 0969.

In addition the Hammersmith store is now remaining open, though it will close for a few weeks in the Spring so that we can give it a face-lift.

Before making any long journeys to any of the new sites, please telephone to ensure the shop is open. If there's no reply then we're probably not open yet!

## Strongest Magnetic Material

A new material currently being marketed by Philips under the name 'Neodure' is claimed to be the strongest and most powerful magnetic material in the world. It is a combination of neodymium, iron and boron which produces a typical remanence of over one Tesla and a maximum BH value of 200kJ/m<sup>3</sup>.

## Software Pirates Still in Business

Three raids on software pirates in Scotland just recently seem to have had no effect in Glasgow's Barrowland market. No prosecutions have yet been brought, but it appears that the same people are still in business. Glasgow CID and the Federation Against Software Theft are investigating.

## Direct Handwritten Computer Input Device

An electronic tablet which lets a computer recognise hand-writing is available from Bergman and Company of London. In its basic form it can recognise up to 37 letters and numbers and treat them as full words. Up until now it has been hard to recognise hand-written input, as different people write in different ways. The Penpad tablet recognises characters by the pen strokes used to write them rather than interpreting the character as a whole.



Astra will be transmitting at 40W per channel (the present satellites transmit at up to 20W), but BSB will be transmitting at 110W per channel and initially on only three channels. Thus it seems likely that the Astra-type dishes will be able to receive both satellites, though the dish will have to be positioned so that it can be swung round to point directly at the two satellites.

# Scouts Show Off Their Electronic Skills



**Reporter: I. A. Duncombe**

**T**o celebrate its 75th year since its foundation in 1913, the Radio Society of Great Britain held its annual convention at the National Exhibition Centre in Birmingham on the 15/16/17th of July. In addition to the traditional stands and exhibits on display at this convention, the centre-piece this year was the Virgin Air Balloon, a real sight to behold! Other exhibitors included the following: the RAF, the Police, DTI, RAYNET, AMSAT and trade companies such as – South Midlands Communications, Lowe Electronics, Garex Electronics, etc. This year as usual, the Scouts Association were there promoting the cause of Scouting activities. The Association was particularly pleased to attend this years' convention, as the RSGB were launching their 'Project Y.E.A.R.' initiative – Youth into Electronics through Amateur Radio – a concept to involve the youth of the country in various training activities connected with electronic project building.

At a special lunch held during the convention, two guest speakers were present: HRH Prince Phillip, who added his support to the RSGB's initiative, and the Chief Scout, W. Garth Morrison DL, who said:

"... During the next two days, I hope that many of you will take the opportunity to visit the stand in the exhibition devoted to radio in Scouting. One of the display panels there, depicts a Sea Scout wireless station which was operating at a scout exhibition a few miles from here at the same time as the RSGB was born. The panel also shows a letter from our founder, Sir Robert Baden Powell, which is just as appropriate today as

it was when he wrote it.

"The letter is in response to an offer from the Marconi Company to teach wireless telegraphy to young people in youth movements. In it, Sir Baden Powell says 'Wireless has become a favourite hobby with boys and it is valuable for them because it has a big future. The Marconi Company has seen the opportunity and have come forward to help and encourage the boys in taking it up.' There are, as I am sure you will agree, some striking similarities between what was happening in 1913 and today."

Incidentally, it seems that Marconi was offering their teaching services free! Even with todays' industry desperate for trained, skilled workers this is unlikely in todays' world!

Mister Garth Morrison continued:

"If you visit the Scout stand, you will see something of the role that radio and its associated technology is playing in the Scout Movement today. You will also see that our stand is alongside that of the Girl Guide Organisation who are also actively providing their young people with an opportunity to discover the excitement of modern communications technology. Between us we represent over one and a quarter million young people... Project Y.E.A.R. seeks to offer young people an opportunity to discover science, engineering and electronics. As such it complements our existing Scout Training Programme, so this is one reason why the Scout Association has an interest in seeing it work."

The Scouts' own commitment to training in the art of electronics currently involves two badges – the Electronics Badge and the Communicators Badge, both require good skill levels to be attained.

"A second reason lies in the fact that we are very much part of an international movement. There are some 16 million Scouts in over 150 countries. Each year international exchanges ensure that young people of many countries come into contact and learn from each other. In 1989, we are holding 11 simultaneous camps throughout the UK with many thousands of young people coming from different countries. During 'Discovery 89', we hope to link the camps through technology and provide means by which our guests can communicate their experiences to those back home. Amateur Radio will play a major role in this."

The most popular and well known event held with the help of radio amateurs is 'JOTA' – Jamboree On The Air. First held in May 1958 and annually ever since in the third full weekend in October, it attracts many supporters among radio amateurs from all over the UK and overseas. The event just held, October 14/15/16 had the participation of well over 7000 amateur stations from over 100 countries involving a quarter of a million Scouts and Guides. In the UK some 500 stations took part averaging about 600 Scout contacts around the world and involving over 12,000 Scouts and Guides. JOTA stations could be found operating from distant places such as the Faroes, Iceland, Bermuda, Azores, Canaries, St. Helena, Gozo, and Hawaii. In fact it seemed that there wasn't many places left out! The best known UK Scout station was GB3GP at The Scout Association Training Centre, at Gilwell Park in Essex. Much emphasis this year was given to the newer of the technologies, such as slow scan TV and RTTY (radio teletype). Even though JOTA is held only once a year, there are still local 'nets' during the summer



Scout camps, jamborees and at weekends. Mister Garth Morrison concluded:

"How wonderful it would be if Project Y.E.A.R. could lead to some form of 'novice' or 'student' license, by which device young people could not only create simple radio transmitters and receivers, but could then use them to communicate with each other, as another way to improve international awareness and understanding.

"Project Y.E.A.R. is obviously an exciting concept designed to provide young people with increased opportunities. This is exactly what the Scout Movement is all about, so you will understand why we are so happy to support it."

Also announced during the convention, much to the unexpected delight of the Scout Association, was the first ever award made jointly by the DTI and RSGB to the Young Amateur of the Year. It was awarded to 14 year old Andrew Keeble from a Scout group in Norwich for his outstanding contribution to amateur radio. As mentioned in Garth Morrison's speech, there continues a dialogue between the DTI and the RSGB for the introduction of a 'novice' license, in which the Scout Association is becoming increasingly involved. The reasoning behind this involvement, is that because a transmitting license requires a sound knowledge of electronics and many youngsters under 10 will not be able to obtain this, if they were to go 'on the air' then they will need supervision. And what better environment for supervision than with the Scouts.

## Maplin to the Fore!

Highlight of the Scout Association stand was the demonstration given to the public of project construction. Among the kits being constructed were a number from Maplin Electronics, including the 'Live Wire Metal Detector' (LK63T) and the 'Siren Sound Generator' (LM42V). Over the three days of the convention, nearly 40 boys, among them Mathew Neale, Andrew Jeffs and Mathew Jackson from the East Birmingham District Scouts, helped build the kits under the supervision and assistance from members of the Northants Amateur Radio group headed by Dr. Roger Hancock. It has to be said that the Scouts' ages varied enormously as did

the complexity of the kits. Nevertheless, the vast majority of the kits that could be built in the time available, and that amounted to nearly 30, were all successfully completed and built to a working condition. It is all credit to the project designers at Maplin that the kits provided were designed with a great deal of care and attention such that anyone with only a limited knowledge of electronics could construct them with ease. A number of young Scouts can be seen building the Live Wire Metal Detector in some of the photographs. Maplin Electronics has always considered that the youth of today are an important audience as regards electronics, and this is no more widely demonstrated than in the approach given to articles and projects in this magazine.

Over 200 people visited the stand each day, asking many and varied questions – answers coming mostly from the boys themselves with a little assistance from the Scout leaders. As can be seen from the photographs, a thoroughly enjoyable time was had by all.

## The Scouts Association

The Scout movement is one of the most progressive youth movements in the world today, with over 16 million members worldwide. In the UK alone, well over half a million experience the fun, friendship and excitement of Scouting. Founded in 1903 by the much revered Baden-Powell, the movement has provided an enjoyable and attractive scheme of training, aimed at encouraging the development of the physical, mental and spiritual needs of young people. Split into four sections, the Scout movement is a multi-cultural, multi-faith organisation comprising: Beaver Scouts – boys aged 6-8 years; Cub scouts – boys aged 8-10 1/2 years; Scouts – boys aged 10 1/2 – 15 1/2 years and Venture Scouts – young men and women aged 15 1/2 – 20 years.

Along-side the Scout movement is the Girl Guides Organisation catering for similar requirements, but of course for girls. There are four sections within the Guides: Brownies; Rainbow; Guide and Ranger Guide/Young Leader which is equivalent to Venture Scout. Note that no discrimination is applied to girls and boys over 15 1/2 years. Membership of either organisation is purely



*A scout uses the magnifier on his 'helping hands' to identify a component value!*

voluntary with funding coming from donations, subscriptions, appeals and so on. Scout Leaders, whose ages may range from 18–65 years do not have to have previous scouting experience, but are nonetheless fully trained at the National Leader Training Centre at Gilwell Park in Essex.

Scouting activities are about involvement and aim to encourage responsibility, self-reliance, the acquiring of special skills and an appreciation of the world in which we live. The importance of team work is emphasised in games which are co-operative rather than competitive. The list of activities the Scout Association caters for is endless; camping, climbing, music, cooking, acting, crafts, sailing, caving, karting, etc.

No matter what your age, race, creed or background, Scouting has something to offer!

## Useful Information

The Scout Association,  
Baden-Powell House,  
Queen's Gate,  
London SW7 5JS  
Tel: 01 584 7030

Radio Society of Great Britain,  
Lamda House,  
Cranbourne Road,  
Potters Bar,  
Herts EN6 3JE  
Tel: 0707 59015

Radio Regulatory Dept,  
Department of Trade and Industry,  
Waterloo Bridge House,  
Waterloo Road,  
London SE1 8UA  
Tel: 01 215 7877

AMSAT (The Radio Amateur Satellite Organisation of the UK),  
The Secretary,  
94 Herongate Road,  
Wanstead,  
London E12 5EQ  
Tel: 01 989 6741



*A study in total concentration as the boys get on with building the projects.*

# LOUDSPEAKERS

## THE FIRST 111 YEARS

### Part 2: War and the first wave of High Fidelity

by J.M. Woodgate B.Sc. (Eng), C. Eng., M.I.E.E., M.A.E.S., M.Inst. S.C.E.

Much has been written about the glamorous (in retrospect) and highly secret development of radar and other electronic systems during the Second World War. The effect of the War on loudspeaker technology was far less exciting, but involved an important principle. Up to 1939, the vast majority of loudspeakers had been designed to operate in the benign climatic conditions of the home, or, for 'public address', outdoors in temperate climates. These same loudspeakers, transported to the African desert, the jungles of the East Indies, or on board ship in the North Atlantic winter, and subjected to 'action shocks' from nearby explosions and impacts, naturally failed very quickly, through distortion or disintegration of the paper cone or the diaphragm, insect attack or corrosion. Corresponding effects occurred in capacitors, resistors and transformers, for which the solution was to enclose the components in sealed metal cans or to boil them in high melting-point wax. Neither version of this 'tropicalisation' process was clearly suitable for loudspeakers! New materials, surface protection and more reliable design and manufacture were introduced quickly under the stress of war. If these lessons had been seen to apply universally, the reliability crisis which hit guided missile electronics in the 1960's might have been forestalled. This crisis, in turn, led to today's industrial quality schemes such as that embodied in ISO9000/BS5750, and, with foresight, these might have been developed twenty years earlier.

### The Civilian Market in Wartime

At the beginning of the war, most of the European radio factories were switched to the production of military goods, and some were damaged by bombing – but not many, because the early bombing was very inaccurate. Later, the British government became convinced of the importance of broadcasting as the best medium for informing and controlling the civilian population, and allowed the production of the 'wartime civilian standard receiver', in mains and battery-powered versions, using components selected from those made for military equipment. These receivers were very well-designed, and



Photo 1a. Loudspeaker at war. A 160mm driver with a bakelised fabric cone was made by RCA for use in this US Navy direct-radiator outdoor loudspeaker. An inbuilt transformer allowed matching to both low-impedance and 'constant voltage' amplifiers.

some are still working today. They used 165mm or 200mm round permanent-magnet loudspeakers, most of which seem to be painted in the characteristic grey of Goodmans.

In the USA, which did not enter the war until December 1941, the household receiver industry continued to operate, mostly producing small, cheap, mains receivers with fairly grotty 125mm permanent-magnet loudspeakers. There was, however, a limited and rather unsophisticated market for more luxurious products, usually with massive cabinets. Since, however, the signal sources were a.m. radio (and American a.m. radio, at that!) and 78 r.p.m. records (with a frequency range of 50Hz to 8kHz), the sound quality was very limited by modern standards. The loudness, however, could be overwhelming, so that development to increase the permissible power input to the loudspeaker did take place.

### The British Industry at War

Meanwhile, Rola, Vitavox and, notably, Tannoy, were making moving-coil drive units and straight and reflex horn systems for the Army and Navy. Tannoy's name became that generally used in the Services for any sound reproduction system, perhaps because they managed to retain their brand-name on some of the products, and the other brand-names were unsuitable as general names ('Give him a shout on the Rola', for instance, unfortunately sounds silly). Tannoy also made cone loudspeakers, both drive units and complete systems in

boxes, headphones and microphones. These are just examples; all the industry in Britain was involved in making what the Services had to have, and companies often found themselves making products designed by their peace-time competitors! A great deal was learned in the five years of the War, and much of this was used to good effect in the following years of peace, even up to the present day. One specific example, which was 'written up' in the August 1946 issue of 'Wireless World', was an inter-ship loud-hailer, made for the Admiralty by Ardent Ltd. This used a 15W amplifier powered from a vehicle battery, together with a bucket-shaped re-entrant folded horn loudspeaker, especially designed to give a very narrow beam of sound, only about 4.5 degrees wide, and an efficiency of about 40%. The beam was so narrow that a sight was required in order to aim it, and the magnet system was made either of Alnico (aluminium-nickel-cobalt-iron alloy) or Ticonal (with added titanium). Early units were fitted with a plasticised paper diaphragm attached to an aluminium voice-coil, which proved unreliable, so they were replaced by an aluminium alloy diaphragm with a copper voice-coil. It is interesting to note that the amplifier is today a museum-piece, whereas the loudspeaker could still be useful in some applications. It was adopted for peace-time use on police cars in Hampshire.

### The Coming of High Fidelity

Although high fidelity sound reproduction has been presented to the general public in two 'waves' of commercialisation, one in the mid-1950's and one in the mid-1970's, the technical history is much more one of steady improvement interposed with sudden, spectacular advances, such as the long-playing disc (1950), the stereo l.p. (1956), the Leak 'Point One' (1946!) and Williamson (1947) amplifiers, the first Quad electrostatic loudspeaker (1955) and the Compact Disc. An early use of the term 'high fidelity' occurs in the title of an article by F.C. Barton in the Journal of the Society of Motion Picture Engineers in March 1934! Such frivolity had no place, of course, in the war-torn European industry of the 1940's. A few stalwart

British enthusiasts, however, constructed such complicated devices as Klipsch and Voight folded horn cabinets out of disused furniture. (You couldn't get the wood, you know.) Even after the war, economic recovery was slow in Britain: the August 1945 edition of 'Wireless World' contains advertisements (the texts of which would have been prepared some months before Japan surrendered after suffering two atomic bomb attacks) for public address amplifiers ('50W at 4% distortion') and horn loudspeakers (at about £13 each), but there are only radios and radio kits for sale, with no mention of high-quality loudspeaker systems for household use. Only the home constructor was being supplied: Bakers offered 300mm and 450mm permanent-magnet drive units with 'triple cone' (a main cone and two subsidiary cones known as 'whizzers' to extend the high frequency response). Advertised 'commercial' loudspeakers (for use in radios etc.) ranged in size from 90mm to 300mm, some at prices quite similar to those of today, in spite of all the intervening inflation! But, in the February 1946 issue of the same journal, the Leak 'Point One' amplifier (10W output with the then incredibly low distortion of 0.1%) was advertised (albeit at low-key), along with Rola, Stentorian and Vitavox loudspeakers. In the August 1946 issue, Goodmans announced a new 380mm drive unit, with 'an excellent response up to 6000 c.p.s. [6kHz]'. The resonance was at 55Hz, the voice coil diameter 50mm, the flux density 1.45T and the 'maximum power capacity 25W peak a.c.', whatever that means. The specification of maximum permitted input is still causing difficulty nowadays. All these loudspeakers had resonant frequencies that were high for their size, and had high total Q. They therefore required very large cabinets if the bass response was to be smooth and not impossibly 'boomy', a feature which was, however, demanded for the newly-introduced 'juke-box'! Even though these products were advertised, most of them were on 'short supply', which meant a waiting list of up to a year or more.

## Radios and Radiograms

As production of household audio products resumed, some manufacturers, such as RGD and Murphy, emphasised sound quality as a feature. RGD's large radiograms had good electronics, and carefully-chosen loudspeaker drive units, but it was Murphy who produced innovations in cabinet design, specifically to improve sound quality. Notable was the A104 'baffle' receiver, whose 'cabinet' was indeed in the form of a curved baffle-board. This receiver used a 200mm round drive unit having an energised (i.e. electromagnet) field, which was becoming a rarity. The sound quality was, and still is, very pleasant but restricted in bandwidth. The radiogram version

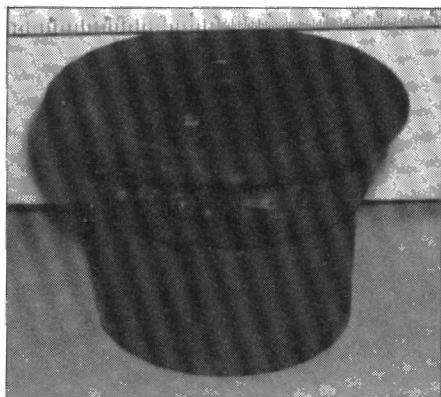


Photo 1b. The drive-unit from the RCA loudspeaker, showing the massive magnet and extremely robust construction. The unit is rated at 20W, and is very sensitive.

tackled the problem of the rear radiation from the drive-unit in an ingenious way. A long strip of single-flute corrugated paper, about 300mm wide, was rolled up into a cylinder about 250mm in diameter. This was then pushed end-on over the back of the drive unit, the turns of the roll automatically displacing to form a conical recess which fitted the chassis and magnet assembly of the drive-unit quite closely. The rear radiation thus entered a mass of long thin tubes formed by the corrugations of paper, and was quite effectively absorbed. It would be unwise to state that Murphy invented this arrangement, because many such ideas were tried and patented in the very early

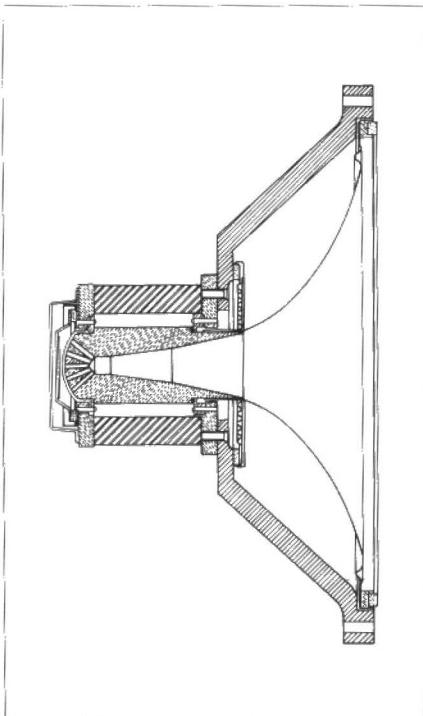


Figure 1. Cross-section of the Tannoy 15 inch dual-concentric full-range driver, vintage 1949. Modern versions are not vastly different in construction, but are improved in many ways.

years, but the idea was 're-invented' in the USA in 1974, in the form of a 'beer-can' loudspeaker, with a 58mm drive-unit. The present author recommends a 'Smash' tin with a 90mm drive-unit.

## Real High-Fidelity

The difference between 'pleasant' sound and 'high-fidelity' sound had, up to the end of the War, been poorly understood. If the sound was pleasing in spite of the loudspeaker bass resonance being poorly damped, and the falling treble of the loudspeaker response was compensated by the rising response of a pentode valve (tube) without negative feedback driving a nearly constant current through the inductive loudspeaker impedance, why bother to strive for flat responses from the amplifier and loudspeaker individually? (A look at the curve of distortion against frequency might answer that!) This, and other similar considerations which are fundamental to the 'British' concept of high fidelity, were not well understood in Britain until the late 1940's, and have still not been fully appreciated in some European countries. But the introduction of disc records with a wide bandwidth (e.g. Decca Full Frequency Range Recording, 'ffrr', 30Hz to 14kHz), and the prospect of high-quality VHF (f.m.) broadcasting, prompted the development and publication, in 1947, of the classic Williamson amplifier design, and a great increase in the interest in 'real' high-fidelity. Williamson's introductory article is still valid, although he is unduly harsh on tetrode valves (tubes), but no doubt, without feedback they had been unduly harsh on him, on occasions! The interest in high-fidelity was largely confined to the enthusiast with some technical knowledge and home-constructor facilities, although some high-quality complete loudspeaker systems began to appear. One of the most interesting was the Vitavox 'Bitone', which used a 300mm bass-unit in a reflex enclosure, together with a multicellular horn (a Vitavox speciality) above 1kHz. The cabinet was 813mm high, 508mm wide and 533mm deep. This was, indeed, a forerunner of the modern 'bass bin and h.f. horn' system. Of course, only one was needed, since commercial stereo was 10 years ahead (although the principles had been patented by A.D. Blumlein in 1931) but such massive enclosures were still the rule when the high-volume manufacturers began to offer high-fidelity to the general public in 1958 (and are still made, even larger, mainly for the US and Middle-East markets today). The cost and bulk of these cabinets led to many ingenious (and usually ghastly) attempts to circumvent the laws of physics with complex constructions intended to give improved bass response from a small cabinet volume. Since it can't be done, they could not do it. The best designs simply explored the true limits of the physical laws. The bass reflex cabinet, in which the rear radiation of the drive unit is allowed to escape from the front of the cabinet through a vent, or a group of perforations (distributed vent), appeared in the 1930's, as a result of research by Thuras in the USA, and at least one British

console record-player (the Sound Sales 'Polyphonic Electrogram') used a 'phase inverter' or bass-reflex enclosure. But the correct design procedures were not known until the classic paper was presented by Dr. Neville Thiele in 1961 (and very little known until this paper was reprinted in JAES in 1971).

## Not all Strange Designs Prove Failures

Baruch and Lang showed that surprisingly good results could be obtained from a group of four 125mm commercial drive-units in a specially-designed enclosure with a distributed vent and an internal perforated partition acting as an acoustic mass + resistance element. The operating principles are now well-understood, but the results, for the low price (under US\$30) at which the system could be sold, were astonishing at the time, and the volume of the box was 'only' 13 litres. Another form of distributed vent was used (whether consciously is unclear) in the R-J loudspeaker, which used a large drive unit loaded at the rear by a closed box and at the front by a duct. The drive unit was mounted on a sub-baffle spaced from the cabinet front, so that there was an annular air-leak around the edge of the sub-baffle. This acted as a vent, whose impedance characteristic could be adjusted by varying the spacing. The action of this arrangement is complex, because there are losses, possibly nonlinear, due to viscous friction in the vent which may not be negligible, and the air load on the front of the cone may be disturbed by the vent radiation, but good results can be obtained with some drive-units in practice.

An interesting drive-unit design was manufactured by Barker, in which the voice-coil was wound on a resilient sleeve over an aluminium former. The latter formed a continuous tube, and thus acted as a short-circuited turn coupled to the coil. At low frequencies, the system moved as a whole, and the mains resonance was very well-damped by the shorted-turn, but at high frequencies the relatively heavy coil did not move, but the induced current in the former caused it to move and so to drive the cone. One problem with this arrangement was that the temperature of the coil had to be limited to avoid 'cooking' the resilient layer, which tended to age and become stiffer in any case. The Barker loudspeaker had a bakelised linen cone, and the designer went to considerable pains to design the cone according to rules which would be well-respected today, taking into consideration the need to provide a progressive and controlled transmission loss in the cone material, and to ensure that there was no discontinuity at the junction of cone and surround which would reflect energy back into the cone and set up standing-

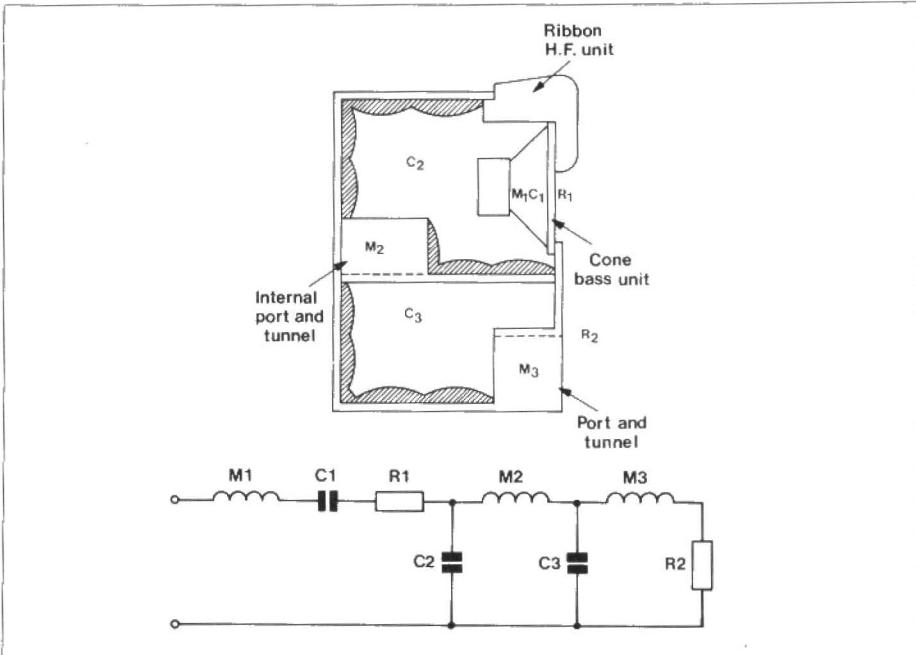


Figure 2. Cross-section, and simplified equivalent circuit at low frequencies, of the Acoustical (now Quad) Corner Ribbon Loudspeaker (1950). The equivalent circuit is clearly a high-pass filter.

waves. With its heavily-damped main resonance and wide potential bandwidth, this drive-unit might have benefitted from constant-current drive, rather than the normal constant-voltage. Another development which was exploited at this time (by Truvox, initially, in the late 1940's) was the 'Wafer', or 'inverted' drive-unit, in which the magnet assembly was placed inside the cone instead of behind it. This was made possible by the introduction of yet more efficient magnet alloys and magnetic circuits, but the obstruction caused by the magnet, and the need for a very long voice-coil former, made the high frequency response rather 'average'.

## Ten-inch Tweeters

One curious feature of these times (1945 to 1954) was the use, notably by Wharfedale, of drive-units as large as 250mm as tweeters (although this term was not in polite use). Even allowing for the use of light, hard cone pulp, so that considerable reduction in the effective diameter was achieved by break-up, the high-frequency radiation must have been in the form of a very narrow beam, and the tonal balance must have varied considerably if the listener moved off-axis of the loudspeaker. The need for a small radiator to cope with high frequencies without excessive 'beaming' was, however, known. Tannoy and WB (Stentorian) produced concentric systems, in which a high-frequency horn-loaded drive unit radiated through the hollow pole-piece of the bass driver. In the Tannoy unit, Figure 1, the bass cone formed (and still does, for what is essentially the same design is still marketed, and is very popular as a British export in Japan!) an extension of the h.f. horn, while the Stentorian had a separate central horn, looking like a 'whizzer', but

attached to the centre pole instead of to the bass cone. The Acoustical Manufacturing Company (now Quad) had, in 1950, the 'Corner Ribbon' loudspeaker, in which the bass was produced by a cone driver in a 'double-chamber' reflex cabinet and the high frequencies by a ribbon tweeter, Figure 2. In the double-chamber system, the enclosure is divided into two similar volumes, with a communicating port (maybe with a tunnel). One volume is driven by the bass drive-unit, while the other has a port (with a tunnel) which radiates the sound from the required face. This system was revived on the Continent in the early 1980's, but has never proved very popular. However, the electrical equivalent circuit was well-understood by the manufacturer, and is clearly that of a sixth-order high-pass LC filter. Perhaps if Peter Walker had not been intent on developing an electrostatic loudspeaker he might have developed the full theory of vented enclosures ten years before Neville Thiele did so! Even more surprising is the closed-box case, where D.E.L. Shorter called attention to its high-pass filter nature in 1950, but the full theory was not published until 1972, by Richard Small.

Another interesting product was introduced by Vortexion, originally in the form of an active, bi-amplified loudspeaker system, long before these terms had been thought of! Indeed, for some years it was called the 'Stereophonic' system, because the bass driver was mounted on the left of the cabinet front and the high-frequency driver to the right. This was not 'stereo', of course, as was well-known at the time, but there was no Trade Descriptions Act in those days (nor any stereo broadcasts or commercial stereo records, of course). Nevertheless, the reduction of intermodulation and Doppler distortion

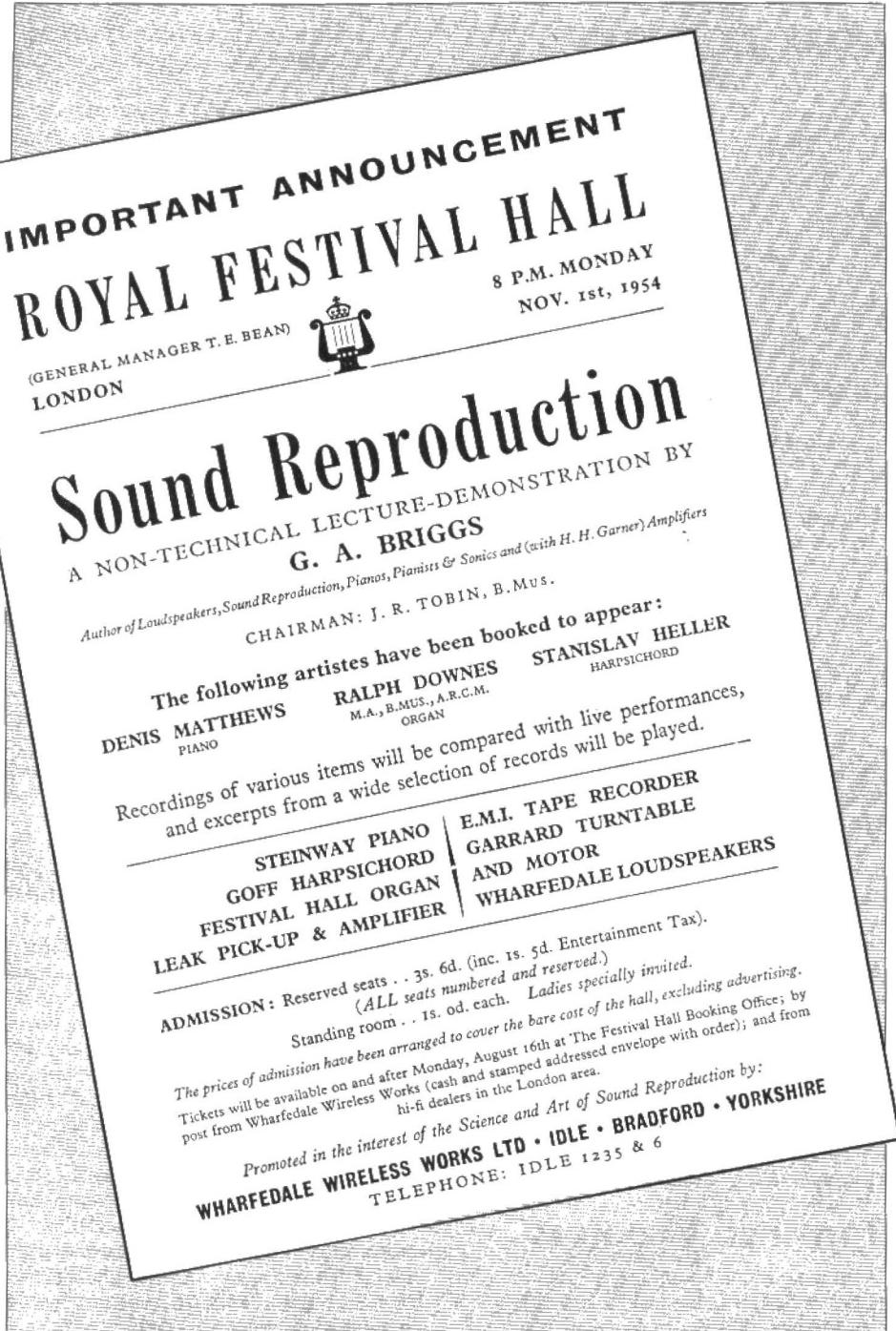


Figure 3. Advertisement for a live-versus-recorded demo by Gilbert Briggs in the Royal Festival Hall. Note the calibre of the artists, and the admission price!

brought about by separating the high- and low-frequency amplifiers and transducers was recognised (although the latter effect was felt by other experts to be negligible compared with other distortions in the then-current systems). Doppler distortion arises from the change in observed frequency of a source which is moving relative to the observer. If a single loudspeaker cone is radiating both a bass note, say 60Hz, and a high note, say 2kHz, then as the cone moves towards the listener under the influence of the 60Hz signal, the 2kHz signal will appear to rise in frequency, and as the cone moves away again, it will appear to fall in frequency. Effectively, the 2kHz signal is frequency-modulated at 60Hz. At the time, however, amplifiers and loudspeakers were such that the maximum amplitude of cone movement

was quite small, perhaps 2.5mm peak. The peak cone velocity at 60Hz would thus be about 0.3% of the speed of sound, and this is also the peak deviation of the frequency modulation. It represents a vibrato of about one tenth of a semitone, which is not likely to be audible, and harmonic distortion of about 7%, rather more audible! This indicates a good reason not to strive for too much bandwidth from any driver having appreciable excursion. The use of two amplifiers with a low-level crossover network was in order to overcome the losses and unpredictable behaviour of passive, high-level networks. The attenuation rates claimed for the crossover were extraordinarily high, 28dB in the first octave, which implies 4th-order filters if they were of the all-pole variety, but they were probably a

type having at least one zero in the stop-band, implying an uneven response in the crossover region, and the phase characteristics would have been rather poor. Later, the amplifier alone was offered, for connection to any suitable loudspeakers. Users were advised to keep the low- and high-frequency units separated, to avoid 'pressure-wave modulation' of the high-frequency unit. This effect would have been greater on large, light cones than it is on present-day dome tweeters.

A very simple way of improving the high-frequency dispersion from a large cone was the slot diffuser, invented by Roger Chapman and R.H. Trier. Instead of a circular hole being cut in the mounting-board, the loudspeaker faced a vertical slot, which diffracted the high-frequency 'beam' from the cone into a wider angle in the horizontal plane. This was used in a BBC design, with a 380mm driver and a 190mm wide slot. For such a large cone, beaming occurs even at 1kHz. Some other designs were less satisfactory: STC (who were Chapman and Trier's employers, but in a different division of the company) produced a loudspeaker for sound reproduction in which a 300mm unit faced a slot only 40mm wide. The stiffness of the volume of air trapped between the cone and the mounting board resonated with the mass of air in the slot to produce a rather nasty lift in response at mid-frequencies, good for sensitivity but not for fidelity!

It should not be assumed that the results obtained with systems including large tweeters were completely unsatisfactory. The directional responses would not bear comparison with the best of today's products, but most system sensitivities were notably greater (essential in view of the limited amplifier power available; a 10W amplifier was most popular) and Gilbert Briggs courageously held numerous demonstrations of 'live-versus-recorded' music, using his Wharfedale products, Figure 3. These were extremely popular, and extremely effective, even convincing to many of the 'golden ears' of the day. The first demonstration held at the Royal Festival Hall saw all 3000 tickets sold out in only 4 days, and the subsequent events were no less popular. Clearly, a sizeable percentage of the public was very interested in high-quality sound reproduction.

## Elliptical Loudspeakers

The trend to make household electronic products smaller led to the development of drive-units with elliptical cones. Much work was done on these at EMI, and technical advantages were claimed. One of the problems that could affect circular cones was the development of 'bell-modes', in which the cone vibrated in a way similar to the opening and closing of flower petals. This can give rise to gross distortion over a

narrow frequency range, and colouration of the sound. Elliptical cones are more resistant to this effect, but have their own modes of undesirable vibration, especially if the eccentricity of the ellipse (not that of the voice coil!) is great. The author remembers an American 320mm x 52mm unit in which the cone vibrated like a tight-rope walker's pole (up in the middle and down at the ends) over a range of frequencies near 1kHz, and produced almost all harmonics, with very little fundamental, in doing so.

## The Mid-50's Revolution

Writing in early 1951, a commentator could reasonably say that not much had happened in the audio field for some years. But the seeds of change were sprouting. WB had already experimented with a separate horn-loaded 'pressure' tweeter but were coy about advertising it, even after rivals Wharfedale introduced their 125mm cone tweeter, with an effective cone diameter of 90mm. The introduction of these drivers prompted one supplier of loudspeakers and accessories to say that 'a crossover network is definitely desirable! The modern mind boggles at the application of the whole audio spectrum to a 90mm tweeter.'

Another development, announced by S. Klein in 1951, was the 'Ionophone' loudspeaker, in which the sound is produced from a column of ionised air. The ionisation is produced by a high voltage at radio frequency (27MHz was used in commercial versions), to which was added the audio signal, also at a high voltage. The transducer has a high acoustic impedance and thus requires horn loading to match to free air. Practical limitations restricted the frequency range to above 3kHz, and a number of units were sold in Britain, first by Plessey and later by the newly founded Fane Acoustics, under the 'Ionofane' brand. The principle was abandoned, but only after seventeen years, due to the (then) inconveniently high lower limiting frequency, cost and problems with r.f. radiation. Given a very well-damped horn, usually achieved by loading with Plasticene the thin, spun aluminium part supplied with the unit, quite good results were obtainable.

A large number of new products were introduced in 1952, and the Government of the day took steps to damp down enthusiasm by suddenly imposing 66% Purchase Tax on all cone loudspeakers of 12 inches or less in diameter. Since this was calculated on the trade price, it not only increased the retail price sharply, but disclosed the retail margin on each product! There are few positive things about VAT, but at least it doesn't involve problems of that nature. Typical of the new products was a range of enclosures with sand-filled panels, introduced by Wharfedale. Non-resonant they were, but enormously heavy as well. Ferguson even had a

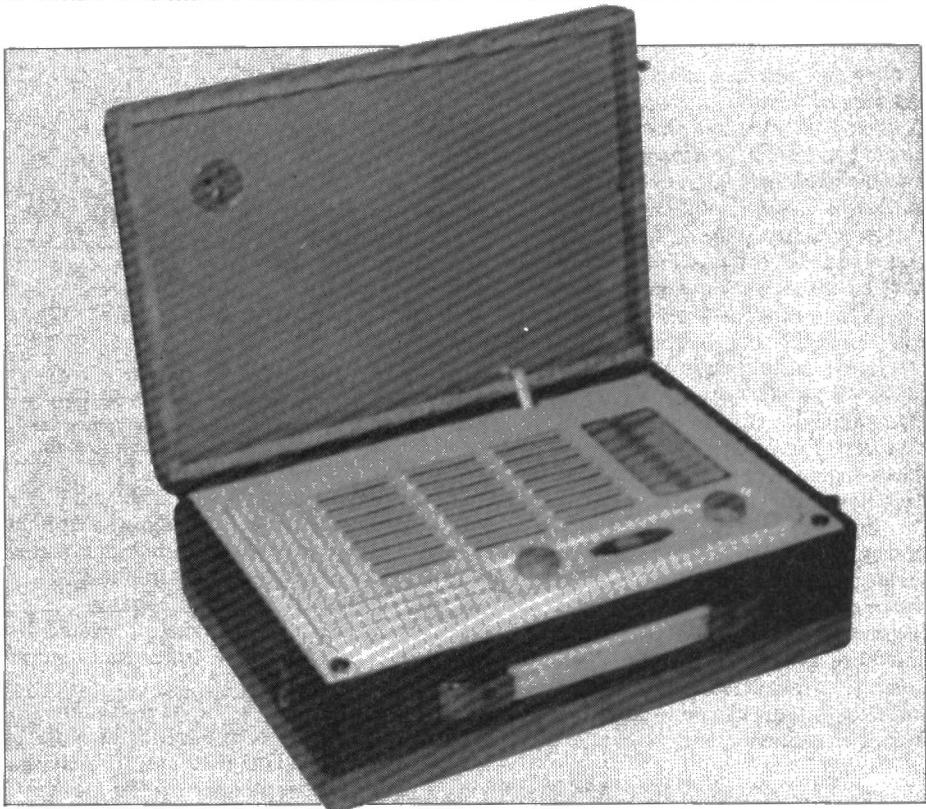


Photo 2a. Vidor battery portable radio of the mid-1950's.

push-pull amplifier and a 300mm/125mm two-way loudspeaker system in a new radiogram, the model 500. The bass unit was loaded by a double-chamber enclosure and the crossover network was said to include compensation for loudspeaker impedance variations with frequency (Zobel networks?) and to have low inter-driver phase-shift. If so, this product was considerably in advance of its time. On the other hand, a new HMV model used two 340mm elliptical drivers, and is likely to have had a less satisfactory directional response. GEC demonstrated two-channel stereophony at the 1952 Radio Show (but called it '3-D sound!'), using F.H. Brittain's 200mm metal-cone loudspeaker. This was a remarkable development, based on very extensive and painstaking research, which, most importantly, included many listening tests. However, there was some luck as well. Hugh Brittain confessed once to the present author that the three 'dunches' in the cone, which removed a nasty h.f. peak, were introduced purely by instinct that they would work, and the explanation came later. Not only did this loudspeaker sound good, its performance was very stable, so it could be used as a reference sound source for the development of microphones and hearing aids. The story of the metal cone was written up by Mr. Brittain in the November and December 1952 issues of 'Wireless World', and these articles are still interesting today. Since the evolution of the loudspeaker depends on that of its associated equipment, it is as well to mention that the same journal saw the publication of Peter Baxandall's now ubiquitous tone control circuit in October 1952. Other related developments were the household reel-to-reel tape recorder (either as a complete product or a home-constructor design), the

inexpensive crystal pick-up (comparable in quality with magnetic pickups of the time, but much easier to use because of its high output voltage) and, at the other end of the recording chain, reliable, high-quality capacitor microphones. Amongst all this high-fidelity, it is also notable that the GTV company of Copenhagen introduced a range of friction-driven loudspeakers (see Part 1 of this series), some of which had a crank-handle to turn the drum manually! These were, of course, intended for outdoor sound reproduction in remote areas.

## The Lull before the Storm

In 1953, there was a dearth of announcements about new developments, but WB created some interest with a new range (the HF series) of drive-units with cambric cones, at very attractive prices. GEC released production series 'FR' metal-cone drivers. In the cinema (remember the cinema?), 'Cinemascope' and other wide-screen formats were introduced. The cinema industry has always favoured systems of stereophony which include three front channels, and the Cinemascope system included a fourth 'effects track', intended to be reproduced by a spaced array of loudspeakers at the back of the auditorium. But nearly another 30 years would pass before the high-frequency response of cinema sound would be extended above 6kHz, through the efforts of Dr. Raymond Dolby. Consequently, cinema loudspeakers in the 1950's were large direct-radiators or horns, and the inadequacies of these at high frequencies were irrelevant. Meanwhile, the column array was becoming popular for sound reproduction. In this device, a vertical

array of identical drivers is arranged in a tall, narrow enclosure. Properly designed, such an array concentrates the sound into a wide, horizontal beam, with narrow distribution in the vertical plane. But proper design is difficult, since the drivers require different, and closely controlled, drive levels. Furthermore, the frequency range over which the required directional response is obtained is rather more limited than is desirable, so that at least two parallel arrays of different-sized drivers are really required if extended high-frequency response is to be obtained. The column loudspeaker has thus become unpopular in the 1980's, and the cluster array is generally favoured.

In 1954, Pye Ltd. released the first (monophonic) 'Black Box' household high-quality record player. This had a rather special 165mm loudspeaker playing out of each side of the cabinet, and these were wired with opposite polarity, so that the record-playing unit was substantially in a node of the sound field, thus reducing the acoustic

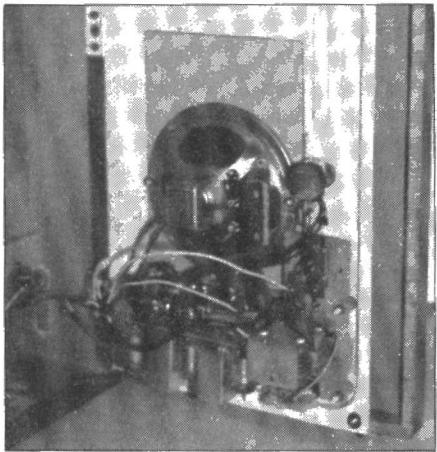


Photo 2b. Interior of the Vidor radio, showing the loudspeaker in situ.

feedback to the pickup cartridge and flattening the overall response considerably. Pye would not disclose details of the loudspeakers (of course!), but at least some were supplied by R&A, not Pye's usual supplier but makers of mechanically superior drivers that were normally too expensive for high-volume household products. This product proved very effective in introducing totally non-technical people to better sound quality. The wiring of the loudspeakers effectively made the sound source a spaced dipole radiator, which produces intriguing subjective effects when used in a room: there is a 'difference' in the sound quality that cannot easily be described, compared with the reproduction from a normal unipolar source.

## The Storm

The first high-fidelity revolution began in 1954. Electrostatic and piezo-electric tweeters of Continental manufacture began to appear on the British market. These were small, so they gave wide-angle distribution of the sound, and cheap, so that home

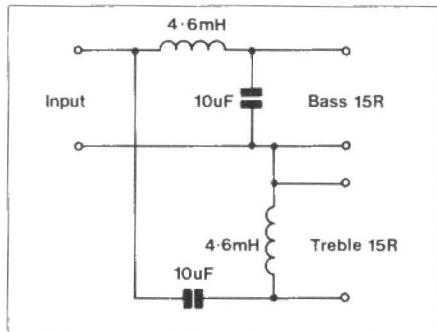


Figure 4. Example of a 1950's crossover network designed using non-optimum principles (i.e. not right!).

constructors could try them without breaking the bank. But the less said about their distortion characteristics, the better. This was a pity, because extended high-frequency response became associated with harsh, intermodulated and unnatural sound - 'Chromium-plated Top'.

But the real start of the revolution was caused by the publication in mid-year of the Mullard '5-10' and GEC-Osram '912' home-constructor amplifier designs. Unlike the previous Williamson and Baxandall designs, these new offerings didn't require such expensive output transformers, and the result was that thousands of teenage enthusiasts (who had far less purchasing power in those days) could afford to build their own amplifiers. Not only for hi-fi; these amplifiers were also suitable for sound reinforcement and reproduction, and there was a considerable demand from the non-technical friends of these youngsters for the newly-popular 'record dances' (ancestors of the disco) as well as for sound equipment for live music events. Naturally, all these amplifiers required live loudspeakers, the sales of which boomed. Record dances were usually run with two 250mm drivers in closed, 60 litre boxes, driven from a single 10W or 15W amplifier, which sounds ridiculous compared with a modern disco rig, but the participants were quite satisfied with the quality of their entertainment. For outdoor events, the 42 inch (1067mm) exponential horn, with a pressure drive unit, was most satisfactory, and these are still used



Photo 2c. Close-up of the 125mm Celestion loudspeaker. This would have had to be very low-cost (about 20p!), but quite sensitive, because the audio output was only about 250mW at most.

today. For better music reproduction, column arrays were sometimes used outdoors, although the cost and weight made them less favoured.

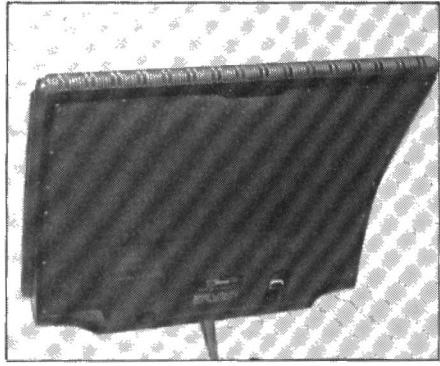
## The Market that Grew too Fast

To cater for the increased interest in high-note response, Plessey, for example, introduced a 380mm bass driver, with a 178mm x 100mm elliptical high-frequency unit mounted within the cone angle of the bass unit. This formed a coaxial source, but the mid-frequency response was badly compromised by the obstruction of the bass unit radiation by the body of the tweeter. There are other examples of products being designed and marketed without sufficient foresight at this time. One example is the design of crossover networks as if they were intended for use between matched, resistive source and load. There was some excuse, as this was usually the only



Photo 3a. Possibly the most revolutionary loudspeaker ever, the original QUAD Electrostatic.

case considered in the text-books, but the audible results, and simple measurements, should have indicated in practically every case that quite different values of capacitance and inductance were required to get a smooth response (unattainable, in fact, with the second-order Butterworth filters which were the usual type recommended) and the correct crossover frequency, Figure 4. Unfortunately, some crossovers are still offered today, designed on these incorrect principles, because, while it is fairly easy to show that 'constant-k' filters are not appropriate, it is also fairly easy to show that practically every other type of filter is also unsatisfactory in some respect. Some of the best compromises were not, in fact, worked out until the mid-70's (Linkwitz-Riley) and early 80's (Lipshitz-Vanderkooy). Yet another curiosity of the time was the decision of WB to produce a range of drive units with two similar (bifilar?) voice coils. These could be connected in parallel to produce a 3.75 ohm coil, or in series to produce a 15 ohm coil. One coil alone would produce a 7.5 ohm unit, but the manufacturer did not stress that the permissible temperature-limited power

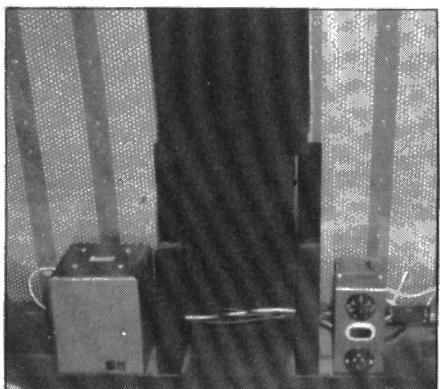


**Photo 3b.** Back view of the QUAD Electrostatic, showing the housing in which are the power supply for the polarising voltages, the step-up transformer to produce the high audio-frequency voltage required, and the 3-way crossover network.

input would be halved in this condition (did he realise?). There is another snag with this arrangement. In the equations determining the characteristics and performance of a loudspeaker, the length of wire in the voice coil plays a prominent part, and in 15 ohm operation the effective length is twice that in the 3.75 ohm or 7.5 ohm conditions. One is thus dealing with what is effectively a different loudspeaker, requiring a different enclosure design!

## The Quad Electrostatic

In 1955, Peter Walker, of the Acoustical Manufacturing Company, accomplished the feat of turning the whole high-fidelity loudspeaker industry green (with envy, of course) overnight. The Quad Electrostatic loudspeaker was a push-pull design, incorporating the important principle of constant-charge, achieved by applying the polarising voltages not directly to the moving elements of the individual drivers but through high resistances. These features allowed the production of a low-distortion system with sufficient bandwidth for faithful reproduction of almost all music (there was a problem with very low bass



**Photo 3c.** Interior of the QUAD Electrostatic. The mains transformer is behind the input panel on the right, and most of the electronics (all solid-state, even in 1956!) is in the grey box on the left. The two bass modules are to the left and right, while the felt curtain in the centre hides the mid-range and high frequency drivers.

## Main details of the range of CELESTION PERMANENT MAGNET LOUDSPEAKERS

CHASSIS DIAMETER	MODEL	SPEECH COIL IMPEDANCE OHMS	POLE DIAMETER	FLUX DENSITY GAUSS	TOTAL FLUX	POWER HANDLING CAPACITY
2½"	P2V	3.0	7/16"	8,500	8,000	25W
3½"	P3C	3.0	3/4"	7,700	24,000	1W
5"	P5Q	3.0		8,500	26,000	3W
5"	P5T	3.0		10,500	32,000	3W
6½"	P6Q	3.0		8,500	26,000	4W
6½"	P6T	3.0		10,500	32,000	4W
8"	P8D	2.3		6,200	24,000	5W
8"	P8M	2.3		8,000	31,000	5W
8"	P8G	2.3		10,000	39,000	6W
10"	P10M	2.3		8,000	31,000	6W
10"	P10G	2.3		10,000	39,000	8W
12"	P64	12.0	1¾"	12,500	140,000	15W
18"	P84	10.0	2½"	13,500	350,000	40W

**Table 1.** Part of an advertisement for Celestion Loudspeakers in 1947. The power rating of the 2½ inch unit should be 0.25W!

notes), and a very smooth, resonance-free frequency response. The system consists of two bass, two mid-range and a treble radiator, and, apart from the limited response below 50Hz, the only significant defect in this design is that the mid-range directional response is rather narrow. By modern standards, the maximum sound level is also somewhat limited, but this was no problem at the time. The new design was quickly recognised as a standard for judging other systems, and did much to encourage other designers to produce improved products. In this year, too, schedule VHF broadcasting began from Wrotham, after far too many years of 'experimental' service. As an indication of a trend to higher amplifier powers, Mullard released a 20W design, the '5-20'. This prompted the introduction of high-fidelity loudspeakers to accept larger inputs, of lower cost than the existing types, which were intended mainly for sound reinforcement. Other developments included a 75mm moving-coil tweeter from Wharfedale, and a very early dome tweeter, with a 2kHz to 20kHz frequency range, produced by Reslosound in conjunction with the BBC Research Department.

## 'Acoustic Suspension'

In September 1956, E.M. Villchur presented a paper to the AES Convention in New York which described the principles of a new loudspeaker product (the AR1) from the US company Acoustic Research. Conventionally, most of the restoring force needed to bring the cone of a bass loudspeaker to its rest position had been supplied by the stiffness of the suspension. In this condition, the cone excursion is limited by the restoring force of the suspension becoming non-linear. If such a loudspeaker is placed in a sealed

enclosure to absorb the rear radiation, the volume of the enclosure must be large in order to prevent the stiffness of the trapped air raising the main resonance too much. However, if the suspension force is made very light, and the voice-coil and magnet assembly redesigned to allow large movements of the cone (usually by making the length of the voice-coil much greater than the depth of the gap), the trapped air itself can provide the necessary restoring force with practically no constraint on amplitude due to the onset of non-linearity. Thus a small enclosure, with a correctly-designed driver, can radiate low frequencies at a high sound level. The only penalty is that the sensitivity is reduced, partly because of the long voice-coil and partly because a strong, heavy cone is needed to avoid flexure effects due to the internal pressure in the enclosure. From the marketability point of view, this new development was like a gold-strike: for twenty years the industry had been trying to get decent bass from a small box, and not succeeding. The public responded by buying the products in great numbers. The AR1 was soon followed by other designs because the principle was, legally, not new enough to patent, Table 1.

The eleven years from 1945 to 1956 saw a very considerable extension of knowledge in the loudspeaker field. Most of the groundwork had been laid, which would lead to the definitive design equations for sealed and vented-box systems developed later by Neville Thiele and Richard Small. But much remained to be discovered (and still does!). In the late 1950's and the 60's, attention was focused on the detailed behaviour of cones and cabinets, the linearity of drive units and the phase characteristics of drivers and crossover networks. These subjects, and others, will be discussed in the next part of this series.



# CLUB MED

## GET SMART

Report by Alan Simpson

Something strange is coming over Club Méditerranéé – and for once it has nothing to do with hedonistic delights involving sun, sea, sand and ski. Even the days of those famed beads could be numbered. Yes, the Club has discovered electronics. Already many of their sea and ski villages have among their attractions microcomputer workshops and business training laboratories. Now the Club is introducing the 'Smart Card', a plastic card (the same size and shape of a normal credit card) but with an embedded memory chip. This will keep a check on members' spending at the bar, boutiques or excursion centres.

However, the Club is not preparing for an influx of robots, ET's or scientists. Having been responsible for introducing to mass audiences such delights as yoga, aerobics,

etc, the Club is turning its attention and resources to spreading the delights of the microchip. Having been in the forefront of providing mass escapism, the Club has now added self-improvement to its one hundred

and fifty or so, self-contained villages situated in some of the more exotic parts of the world. The new development may clash with the time-honoured routines of beads and bikinis and a non-encouragement policy for radio and TV, etc, but the Club is taking its new high-tech role very seriously. According to Jacques Benacin, who heads the Club's computing activities, the organisation sees its role as spreading enlightenment, confidence and skills. In fact, the drive behind the workshops comes from the top. Chief Executive, Gilbert Trigano, has a philosophy which involves the breakdown of artificial difference between people – "At heart we are all the same. We now aim to demystify the computer, providing people with confidence and understanding, if not skills."

Bronzed Club Med beauty shows off her 'Smart' card!





Sun, sea and computing! Not such an odd combination.

## Information Technology on Holiday

Having installed computing systems and training in all French universities and schools at the request of President Mitterrand, Gilbert Trigano is now repeating the exercise at the Club Med. The microcomputer workshops provide courses in the basic understanding of computers, to a varied, but always appreciative class. Businessmen attend, keen to have the opportunity of finding out how the computer can assist their particular activity, and students attend hoping to gain enough knowledge to perhaps get a job in the computing industry, while parents are there to help them keep up with their children's computing skills! More mature visitors attend the classes to get to grips with terminals now becoming a feature in their local bank or travel agency. However, at least two microcomputers are reserved for the dedicated electronic game enthusiasts.

As Jacques Benacin says, "everyone is going to have to live with the new technology, so the sooner we get to grips with it, the better." A vacation, he suggests, is perhaps the ideal time to undertake the learning class. Although the classes are carefully structured, the instructors (or GO's as Club Med likes to call them) pace the class at the level of the participants. Classes are usually for two hours a day with basic computing being featured in the morning sessions and more advanced classes in the late afternoon. Often classes are held in the late evening where subjects include business communications and word processing.

Leave the kiddies in the games room, whilst you soak up the sun by the pool!

## Mission Control Graphics

One dedicated visitor to Club Med, Marbella, earlier this year was drawing admiration from his classmates as well as the GO's, for his range of microscreen-based graphics and designs. It turned out he was on leave from the US Mission Control in Houston, Texas!

Another visitor was Ashwin Arora from a chain of chemists in North East London. "When I'm at work, I never have the time to master the computer. Here I can get to grips with basic routines and develop some practical applications." Similarly carried away was Jean Jones of Worcester. "Who will believe," she asked, "that I have deserted the swimming pool gymnastics for a screen terminal." But in her case, it could well have been the attraction of the dishy GO's and the cocktails served at regular intervals!

Ashwin could well be a candidate for the latest Club Med seminar initiative, 'MicroCool 2000'. Here business seminars are designed for specific professions such as bankers, doctors and engineers with industry computing experts on hand to give guidance. The courses involve a half-day of classes for a week, giving plenty of time to fit in some windsurfing, sailing or skiing lessons. But even outside the workshops, Club Med members will find it hard to escape the presence of the micro. Far from being restricted to the classrooms, micros are often located by the pool, behind the sand dunes or close to the après-ski club. Micros are also expected to have a role in village activities, giving details of 'what's on', timing ski or

swimming contests or measuring audience applause at the nightly shows.

## Farewell Beads - Hello Smart Cards

Just in case you manage to avoid the micro, the Club is planning even more positive ways of getting their members involved in high-tech. This year saw visitors to the Club villages in Agadir, Morocco, and Marbella, being issued on arrival with a garland, a Club Med Smart Card plus a Personal Identification Number. The Smart Card contains information covering the members' length of stay, dates and timing of departure. It records details of your spending while at the village with each transaction memorised in the magnetic strip with spending checks set for your children if required. Until now, the high cost of issuing a Smart Card to all members has been a restraining matter. Despite falling costs, each card still costs about £4, compared to less than 40p for a normal plastic credit card, and with over one million visitors a year, the cost would be prohibitive. However, by introducing a multi-user system of operation, up to three members can use the same card consecutively and the high basic cost can be spread. Even so, Jacques Benacin is looking forward to the time when the present 8-bit card will be replaced by a 64-bit card giving eight times the power (and memory) of the present card.

With the bulk of Club visitors arriving and departing on the same day, the Smart Card program will help smooth settlement procedures, and provide booking facilities for village activities. In due course, the personalised card could contain details of the holder's own bank account, thus further speeding the check-out procedures and of course, the Club's own administration.

"Providing we can succeed in balancing the profit and loss aspect of the Smart Card project, we envisage a steady fall in the basic cost of the card, and have plans to introduce the card into over sixty of our villages" says Jacques Benacin. "To date, members are reacting enthusiastically to the new card." With the Club setting the pace, the smart card could soon be taking over from "our flexible friend." As Bill Loose, from PA consultancy, comments: "The use of a Smart Card is as wide as human ingenuity, not only for our shopping, car parking and tickets for 'The Phantom of the Opera', etc, but it will also replace our front door keys, act as your passport, pension book, health register, car log, cheque book and personal diary." Meantime, U.K. organisations showing interest in Smart Card technology include the high street banks, building societies, oil companies, British Rail, British Telecom, the DHSS and the Home Office. Who knows, the fast expanding range of Maplin stores could also join the 'Smart Club'.

But as perhaps can be expected, Club Med are going for status alongside the spreading of awareness. Their card comes attached to an equally smart chain necklace. Now it just remains to be seen if you can persuade your boss (or accountant) that a visit to the Club Med should count as a high-tech training expense!



# Exploring Radio

by Graham Dixey C. Eng., M.I.E.R.E. Part 5

## Introduction to Short Wave Listening

Within a frequency range that extends from 1.8–30MHz approximately there are seven amateur bands and twelve commercial broadcast bands. The seven amateur bands are as follows.

160 metre band 1.8–2.0MHz  
(The above band is shared with maritime stations)

80 metre band 3.5–3.8MHz  
40 metre band 7.0–7.1MHz  
30 metre band 10.1–10.15MHz  
20 metre band 14.0–14.35MHz  
15 metre band 21.0–21.45MHz  
10 metre band 28.0–29.7MHz

Part of the fascination of short wave listening must be due to the fact that, at appropriate times and under suitable conditions, reception from many overseas stations is possible. This is because radio waves of certain frequencies can be 'bent back' towards the earth by the ionised layers of gases, high above the earth's surface, that have the collective name

of 'ionosphere'. These 'sky waves' can bounce (skip) several times between ionosphere and ground and so can cover vast distances. The 'ground wave' for the same frequencies is soon attenuated by absorption and doesn't travel very far at all. Some idea of the heights of the various layers of the ionosphere can be gained from Figure 1. The heights and the intensity of ionisation varies according to time of day, season, etc., so that communication in this way is by no means a certain fact. But then this is half of the fun!

The short wave broadcast bands are as follows.

120 metre band	2.3–2.495MHz
90 metre band	3.2–3.4MHz
75 metre band	3.9–4.0MHz
60 metre band	4.75–5.06MHz
49 metre band	5.95–6.2MHz
41 metre band	7.1–7.3MHz
31 metre band	9.5–9.775MHz
25 metre band	11.7–11.975MHz
19 metre band	15.1–15.45MHz
16 metre band	17.7–17.9MHz
13 metre band	21.45–21.75MHz
11 metre band	25.6–26.1MHz

Of the above the 60 metre through to 19 metre bands are particularly worth exploring.

## Aerials and Earths

A good aerial is essential for short wave reception and can be readily provided under most circumstances. A good way is to suspend a length of wire (20 metres or so in length if possible) between some high point on the house (chimney stack or eaves) and the top of a mast or tall tree at the end of the garden. The anchorages at each end should be such that the aerial itself is insulated from its supports. The downlead would be taken from the near end of the house down into the 'shack', wherever that is situated. This type of scheme is shown in Figure 2. Where such a provision is not feasible, a length of wire run around the loft will often bring in an adequate signal; failing that, try a wire aerial around the picture rail! The aerial itself can be made from stranded, plastic covered equipment wire or from a fairly stout gauge, e.g.

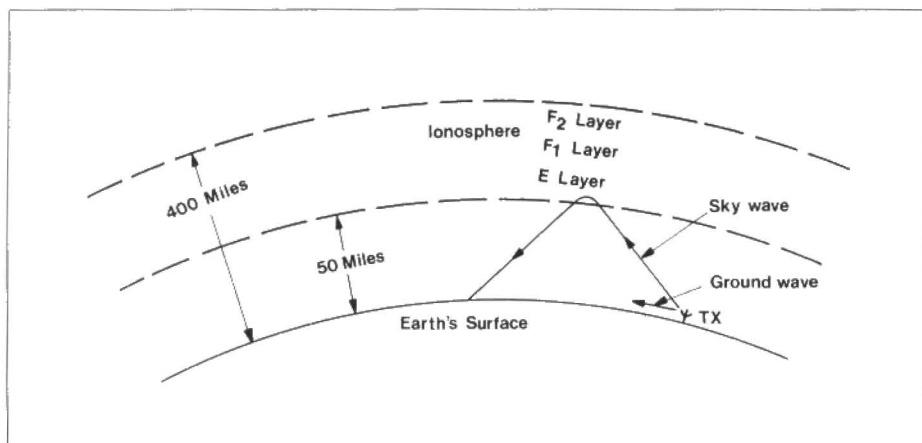


Figure 1. Because of reflection by the ionosphere, at short waves the skywave travels much further than the ground wave.

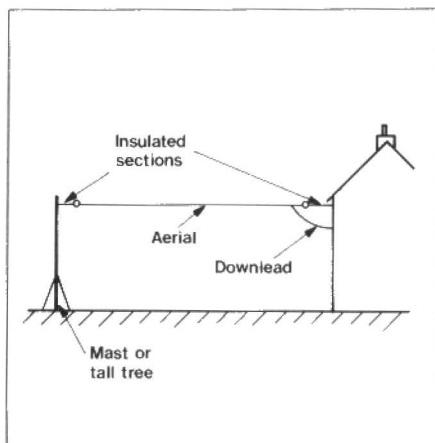


Figure 2. Suitable arrangement for effective SW aerial.

16 swg. of enamelled copper wire.

Whether an earth is of any benefit depends upon the frequency band in use. At low frequencies it may well increase the signal strength noticeably, but at higher frequencies it often has little effect. If it is required, it can be provided by connecting an earth lead from the receiver to a metal spike driven into the ground. Try 'watering' this earth connection before using the receiver; the extra conductivity may give a boost to the signal! An alternative way of making an earth connection is through the domestic plumbing, provided that the pipe in question carries water and not gas!

## The Regenerative Detector

Any radio receiver must have good selectivity and gain. The problem with a simple receiver is providing them in adequate quantities. A common way of doing this is by the use of 'regeneration' or, as it is often known, 'reaction'. The principle is as follows.

If a portion of the output of an amplifier is fed back to the input so as to be in phase with the original input signal, this is termed 'positive feedback'. If there is enough of this feedback the circuit will burst into self-oscillation. This may be deliberate, as is the case with oscillator circuits, or accidental, as may occur if a high-gain amplifier is laid out badly. At the point just before self-oscillation occurs the gain is very high indeed. It is this latter fact that is made use of in receivers employing regeneration. If the amplifier is tuned by an LC circuit, then the frequency of the oscillations will be the resonant frequency of that circuit. This is the case of a radio-frequency (r.f.) amplifier tuned to some station frequency. The gain will be very high at the wanted station frequency and much less at frequencies on either side. Thus, regeneration provides both high gain and improved selectivity at the same time.

The usual way of providing this feedback in a receiver of this type is by means of a coupling coil between output and input in series with a variable component, either a capacitor or resistor, to allow the degree of feedback to be adjusted. This is brought out to the front panel and is termed the 'reaction' control. It is necessary to have ready access to it because the degree of feedback required varies with frequency. Tuning the receiver is accompanied by frequent adjustments of the reaction control - a far cry from the tuning of a modern medium wave transistor portable!



Photo 1. A cheap and easy way of making coil formers - winding thin card strips onto a suitable former and glueing the layers with PVA glue.

## Types of Modulation

Among the types of modulation possible are CW (Continuous Wave - morse transmissions), double-sideband amplitude modulation (d.s.b.a.m. - as used in medium and long wave broadcasting) and single-sideband amplitude modulation (s.s.b.a.m. - much used by amateurs today). A regenerative detector of the type described here, and used in this project, is actually able to handle all three types of signal, notwithstanding its simplicity. It is merely a matter of adjusting the reaction control. Slightly more reaction is required in the case of CW and ssb signals.

## Bandset and Bandspread

There is nothing very mysterious about these terms; they could equally

well be replaced by 'coarse' and 'fine' tuning, respectively, for that is all they are. They are both provided by variable capacitors, that for 'bandset' being of fairly high value, up to 500pF, and that for 'bandspread' having a much lower value. The latter should be set to its mid-position prior to tuning a station. The tuning procedure is that the station is found approximately with the 'bandset' control (which benefits from a slow motion drive) and then fine tuning of the station frequency is carried out with the 'bandspread' control. They are, of course, merely wired in parallel.

## The Aerial Coupling Capacitor

The tightness with which the aerial is coupled to the tuned circuit

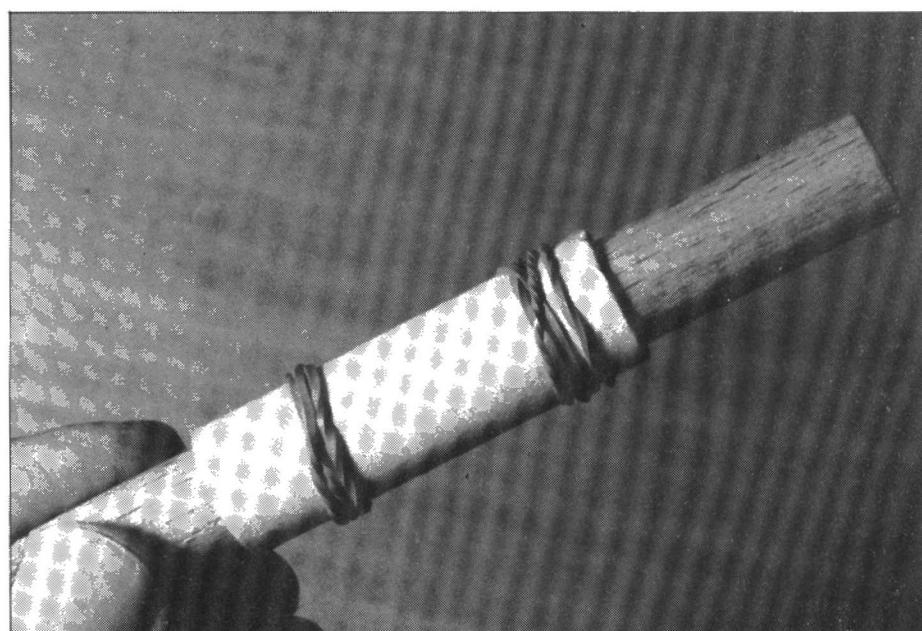


Photo 2. Rubber bands will hold the coil securely until the glue has set.

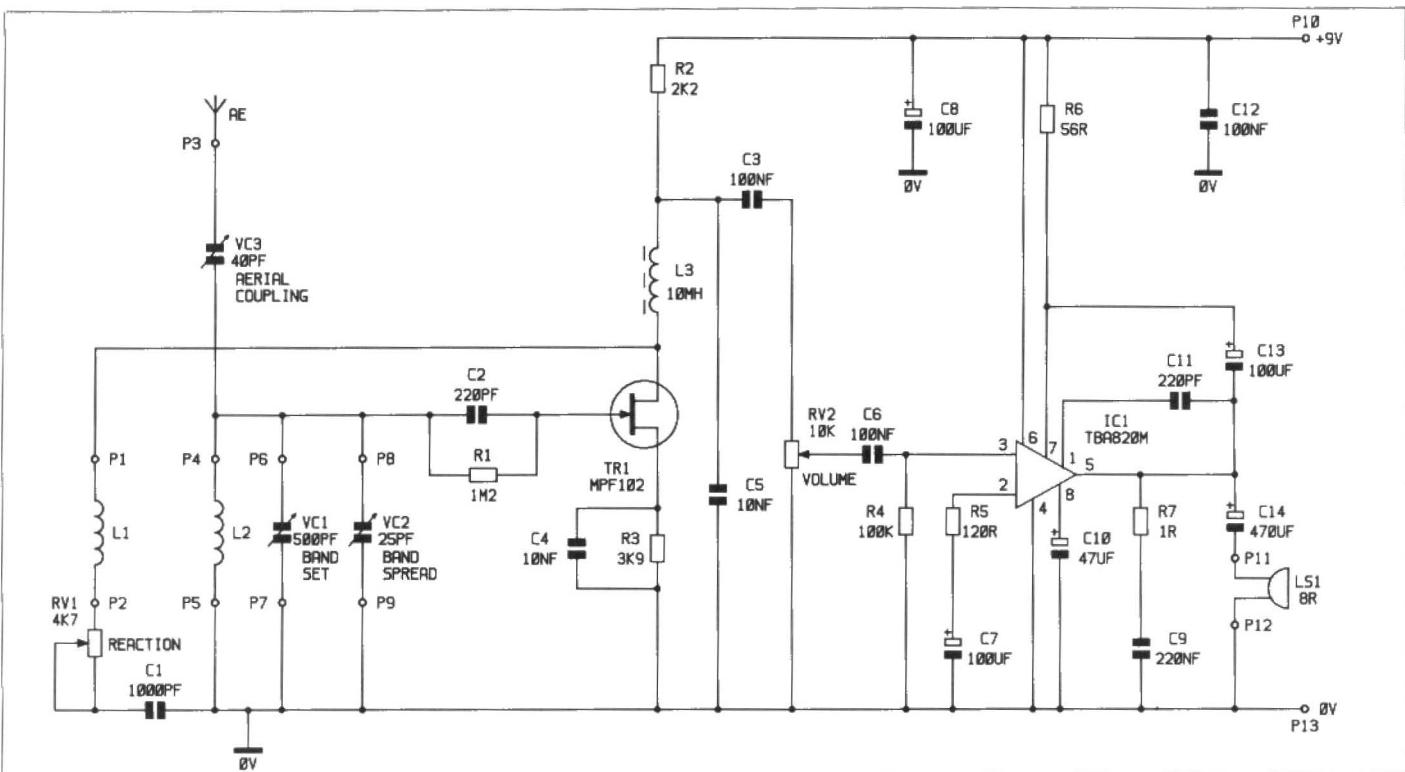


Figure 3. Circuit of the SW TRF Receiver.

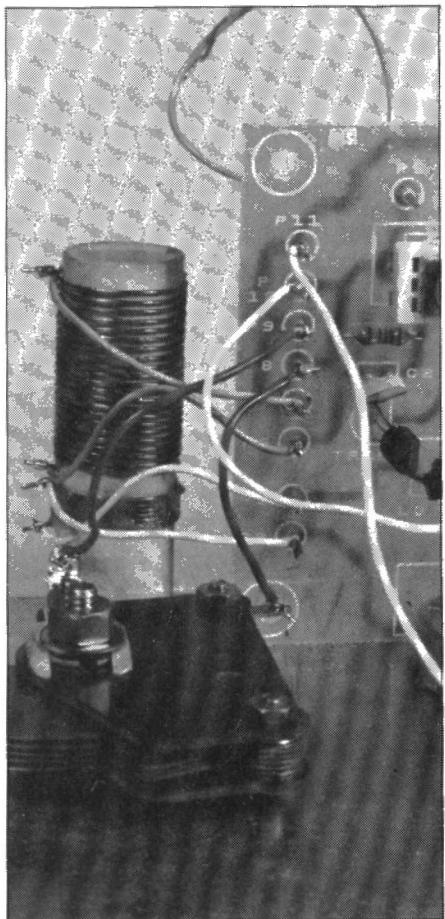


Photo 4. View of the r.f. section of the Short Wave Receiver, showing clearly the coil and tuning capacitor connections.

has two effects. Tight coupling provides the maximum signal; but it also affects regeneration and, at some frequencies, may prevent it from

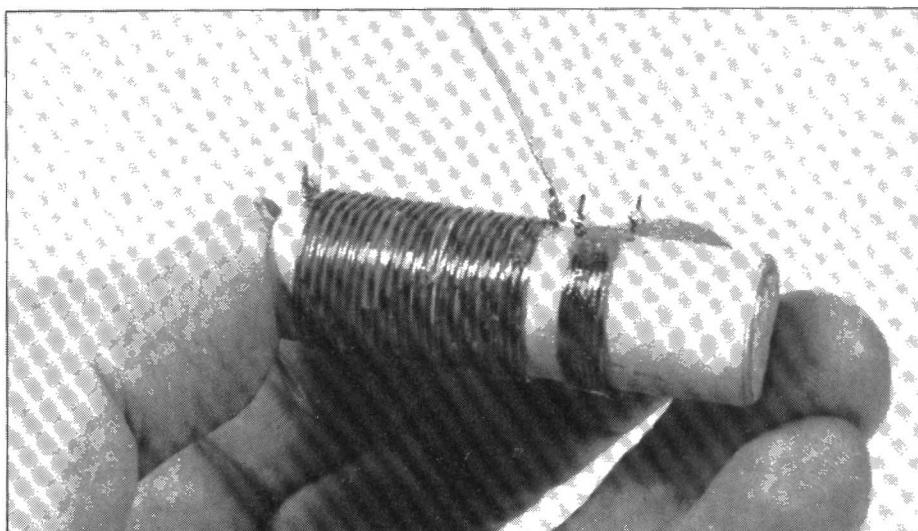


Photo 3. The completed coil. The turns have been secured by passing the ends of the wire through holes drilled through both sides and then using epoxy adhesive.

being obtained. For this reason some degree of control over aerial coupling is desirable. It can be provided by inserting a small compression-type trimmer capacitor in series with the aerial. Normally this trimmer should be screwed most of the way home but, where it is difficult to obtain regeneration, it can be unscrewed slightly, with some slight loss of signal.

## The Complete Short Wave Receiver

There are only two components in the final circuit Figure 3, the r.f. stage which uses an MPF102 Field Effect Transistor, and a TBA820M, IC audio amplifier. Both r.f. and a.f.

gains are high, when the receiver is properly adjusted, and the output sound level is adequate. In fact the TBA820M is capable of over-driving the small speaker specified, so the volume control should be used judiciously or a larger speaker used. In the end it is a question of how much signal is available.

Looking at the r.f. stage first, the controls discussed, 'reaction', 'bandset' and 'bandspread' are readily identified. The main tuning coil is L2 and the reaction coil is L1, both of which are described in detail later. Capacitor C1 is a d.c. blocking component and VC3 is the aerial coupling capacitor. The aerial (Ae) is soldered directly to the wiring pin P3. The parallel combination of R1 and

C2 provides 'automatic bias', essential to the operation of this type of detector. In the drain circuit there are two components, the r.f. choke L3 and a resistor R2. The former is used to develop the r.f. feedback voltage, while the latter is the audio load. Capacitor C5, together with L3, filters out the residual r.f. after detection, since this must not be allowed to reach the audio stage.

The recovered audio is coupled to the volume control by capacitor C3 which, being low in value, gives some bass cut that improves intelligibility. After that the audio is amplified by a perfectly standard IC amplifier that has a 1.2W capability.

## Problems with Coils

It is less easy these days to obtain the components for home construction of receivers. The problem is particularly acute with inductors. Even r.f. chokes above about 1mH seem fairly rare. However, while it may be difficult to find the specified 10mH choke (L3), a 4.7mH choke (4,700 $\mu$ H) should do

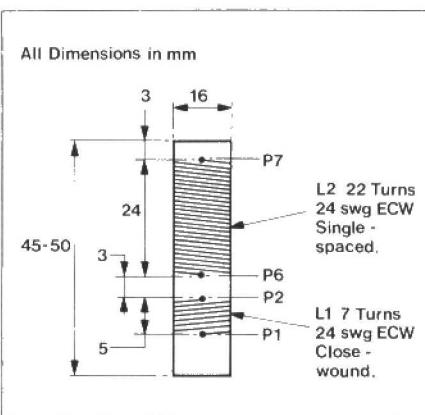


Figure 4. Coil Winding details: Note that L1 and L2 are wound in opposite directions.

well enough; the value isn't critical. Commercial coils would have done for L1 and L2 but these no longer seem to be around so it is a matter of winding one's own. Fortunately, at short waves, inductances are small and the number of turns few. The main problem is obtaining a suitable former. A plastic, Paxolin or fibreglass tube, about 16mm in diameter would be ideal but again

proves elusive. There is an easy answer – make your own! It is done like this.

Obtain a short length of wooden dowel about 12mm in diameter to act as mandrel. Cut a piece of thin card about 45-50mm wide and long enough to wind around the wooden dowel about three or four times. Wrap this tightly around the dowel, putting some white PVA glue between the layers as you do so. When enough has been wound on to produce a former about 16mm in diameter, secure it tightly with rubber bands and leave it to set. When thoroughly dry, drill the holes and wind on the turns as in Figure 4, finishing off with a coat or two of varnish to give it a professional finish as well as to keep out the damp. An alternative to this is to use two-inch wide brown parcel tape, the paper variety, not the plastic type.

The coil shown in Figure 4 should be capable of tuning over the approximate range of 3 – 8MHz with a 500pF tuning capacitor. Notice that the coils are wound in antiphase as this is essential to getting

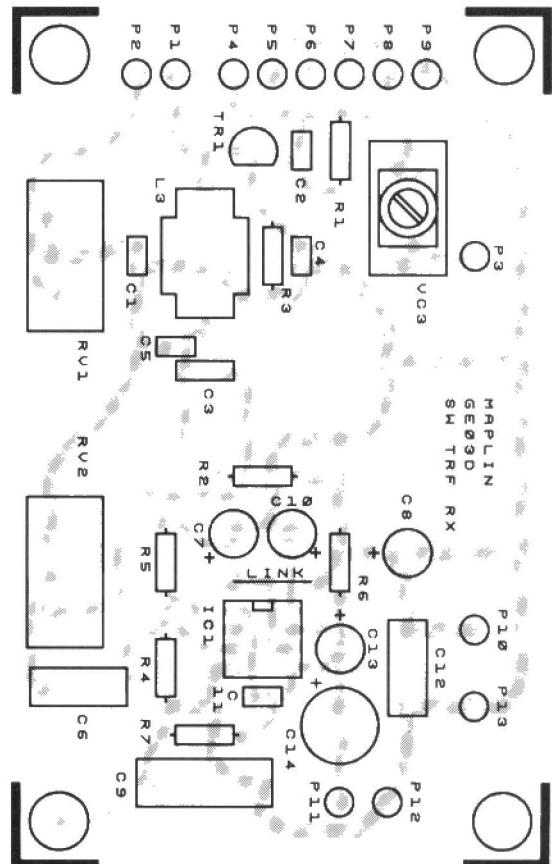
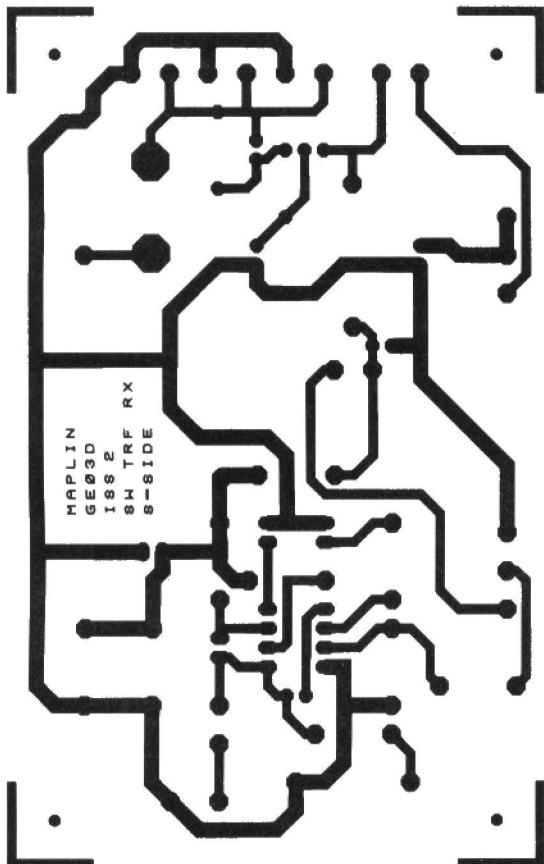
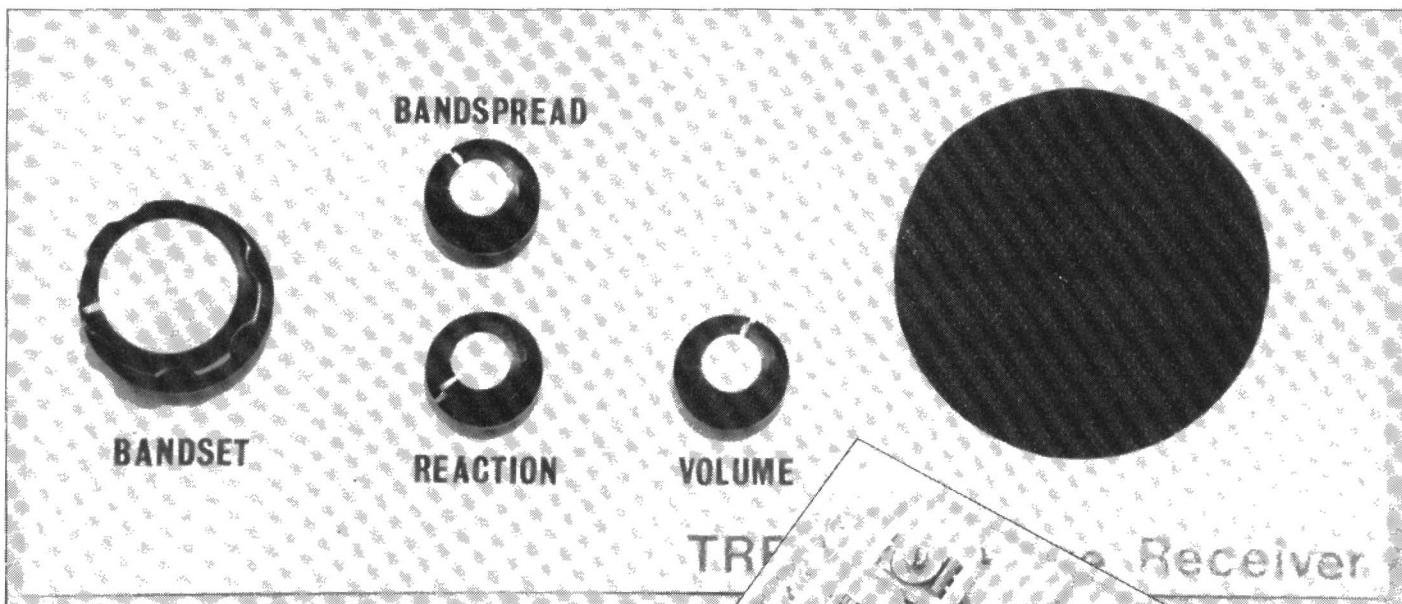


Figure 5. Layout of the PCB.



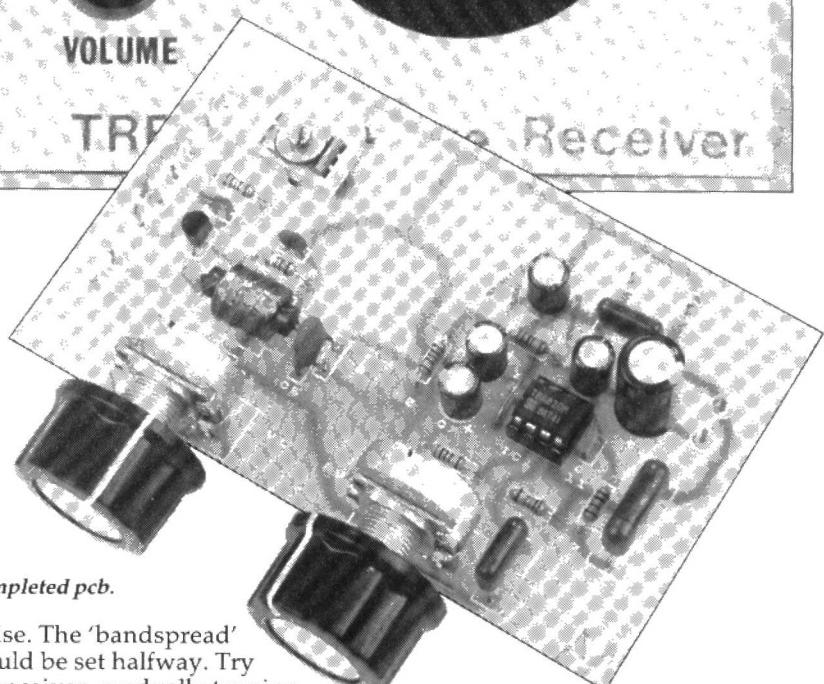
*Photo 5. Possible front panel layout.*

regeneration to occur. If it appears to be absent, there is always the possibility that the winding L1 has been connected the wrong way round. Try reversing the connections to L1. If it still fails to work it may be necessary to increase the number of turns on L1, though it is unlikely. For higher frequency ranges the number of turns on L2 should be reduced, while those on L1 should be increased. As a guide, L2 can be reduced to 10 turns, keeping the same winding length as for the lower frequency coil. The reaction coil should be increased to 10 turns. The spacing between the two coils should be about 3mm. This should allow coverage up to about 16MHz.

### Tuning the Receiver

The procedure has been fairly well explained earlier, but this will sum it up.

Start with VC3 about halfway down and with RV1 fully



*Photo 6. Completed pcb.*

anticlockwise. The 'bandspread' control should be set halfway. Try tuning the receiver, gradually turning the 'reaction' control in a clockwise direction until stations are heard. When on a station, rotating the 'reaction' control further should increase the volume and, eventually, a whistle should be heard as the tuning is swung either side of the station frequency. For best a.m. reception the reaction should now be

reduced slightly. Use the 'bandspread' control to 'fine tune' the station. As mentioned before, if regeneration does not occur, try unscrewing the aerial coupling capacitor further. Some practice and a little patience is needed to get the best results but, when you do, happy DXing!

### SW TRF RECEIVER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	1M2
R2	2k2
R3	3k9
R4	100k
R5	120Ω
R6	56Ω
R7	1Ω
RV1	4k7 Pot Lin
RV2	10k Pot Lin

CAPACITORS

C1	1000pF Ceramic
C2,11	220pF Ceramic
C3	100nF Minidisc
C4,5	10nF Minidisc
C6,12	100nF Polyester
C7,8,13	100μF 10V P.C. Electrolytic
C9	220nF Polyester
C10	47μF 25V P.C. Electrolytic
C14	470μF 16V P.C. Electrolytic
VC1	500pF Dilecon
VC2	25pF SW Trimmer

VC3      40pF Trimmer

(M1M2)	1	(WL71N)
(M2K2)	1	
(M3K9)	1	
(M100K)	1	
(M120R)	1	
(M56R)	1	
(M1R)	1	
(FW01B)	1	
(FW02C)	1	

MISCELLANEOUS

See Text		
Choke 4.7mH	1	(UK80B)
L/S Lo-Z 768	1	(YW53H)
Knob K7A	3	(YX01B)
Knob K7C	1	(YX03D)
8-pin DIL Socket	1	(BL17T)
Veropins 2145	1 Pkt	(FL24B)
PP3 Battery Clip	1	(HF28F)
EC Wire 0.56mm 24 swg	1	(BL28F)
Constructor's Guide	1	(XH79L)
Printed Circuit Board	1	(GE03D)

The following items are available:  
SW TRF PCB Order As GE03D Price £3.95  
Choke 4.7mH Order As UK80B Price 68p

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